A MULTIPLE MICRO-PULSE GENERATOR

John W. Rhinesmith

NERATOR

By:

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FOREWORD

This report describes in some detail the work performed by the author during a thirteen week period extending from 2 January 1952 to about 29 March 1952. It is submitted in partial fulfillment of the requirements of the Engineering Electronics course at the U. S. Naval Postgraduate School, Monterey, California.

The experimentation was carried out at Melpar, Inc. in Alexandria, Virginia.

The report is in a summary format rather than a chronological one. It includes considerable engineering and product detail in order to assist those who may use the unit built, or who may undertake construction of similar units in the future at Melpar.

In the laboratories of this firm there was, at this time, the need for a multiple pulse generator for use in the general development of pulse time modulated equipments. In the course of design of these pulse time modulated equipments, testing was involved which required short S-band r-f pulses. A TS-155C r-f signal generator was modified to furnish these test signals. The TS-155C signal generator itself, however, had to be modulated by a series of very narrow pulses with rise times of the order of a tenth of a microsecond. These pulses were required to be capable of being positioned, in time, as close together as six-tenths of a microsecond, and furthermore they were to be capable, either singly or severally, of being wobbulated at audio frequencies (20 to 3000 cycles per second) up to 1.0 microsecond either side of their normal positions.

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The need for such a multiple pulse generator, or modulator, is the justification for the time and effort expended in its design and construction.

Every courtesy, facility, and encouragement was extended by those who were my associates at Melpar. For this I am extremely grateful.

INTRODUCTION

The design and testing of the pulse time modulated units, mentioned in the foreword required a laboratory layout of considerable flexibility. Both the r-f signal generator and the multiple pulse generator used to modulate it had to meet rather severe requirements as reference to their outputs.

There were not available, commercially, any S-band r-f signal generators capable of being pulsed satisfactorily at such close intervals as the .6 microsecond spacing required. This presented the possibility of either modifying an r-f generator, such as the TS-155C, or of building a new unit employing a pulser tube and cavity that could be triggered at the required time intervals.

Another problem now appeared. This was the question of what to use as a modulator for the r-f generator referred to above. This modulator or pulse generator had to meet the following needs:

It must generate a train of at least five pulses.

These pulses must not be greater than .2 microsecond in width at their 50% amplitude points.

The rise time of an individual pulse must not exceed .1 microsecond.

The individual pulse must not contain a transient that will interfere with a following pulse, when spaced as closely as .6 microsecond (leading edge to leading edge).

The pulses must be of sufficient amplitude to fire the r-f generator which the unit is to modulate.

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The pulses must be of sufficient amplitude to fire the r-f generator which the unit is to modulate.

Each pulse must be capable of being positioned or delayed over a period of at least 0 to 3 microseconds.

Any selected pulse or pulses must be capable of being modulated, in time, sinusoidally at a frequency of 20-3000 cycles per second, with an excursion up to 1.0 microsecond either side of the initial position.

Finally, there must be no cross talk between pulses in the output train.

To meet these requirements, the pulse generator or modulator described in this paper was evolved.

In order that the design and construction of this piece of test equipment might follow a logical and orderly sequence the unit was broken down into ten sections, or so called channels (see drawing EA1).

Channel (A) is a free running blocking oscillator with a control for adjusting the pulse repetition rate. The output pulses from this channel control channels (B) and (C).

Channel (B) is composed of a delay multivibrator and slave blocking oscillator. The output is a positive pulse which can be delayed by adjusting the recovery time of the delay multivibrator.

Channel (C) contains a delay multivibrator, a clipping and stretching pulse shaping network, an audio amplifier and a slave blocking oscillator. A fixed d-c potential, a positive pulse with a stretched leading edge, and an audio frequency sine wave are combined in the grid circuit of the slave blocking oscillator. This combination produces a varying bias which controls the time of firing of the blocking oscillator. The output of channel (C) is a positive going pulse which is wobbulating at the same audio frequency as that audio signal on the grid.

The outputs of these two channels (B) and (C) are connected individually to the contacts of a bank of five single pole double throw switches. Each of these switches selects the pulse, fixed or wobbulated, to be used to control a separate pulse generation channel, similar in circuitry to channel (B). These five channels are labeled (D) through (H).

As has been indicated, each of the channels (D) through (H) produces a single positive output pulse. This pulse is either stationary or wobbulating depending on the pulse selected by the selector swith to control the channel.

The five pulses generated by these channels then are combined in the mixing channel (K). The output of this channel is either a positive or a negative pulse train which can be coded as explained above.

The remaining section, designated Channel J, is the regulated power supply.

A complete block diagram showing the individual stages within the channels is included as drawing EA2. In the following pages, a detailed description of the functions of the channels is given. The channels are treated individually. The description of the action in the final or mixing channel is quite extended and shows clearly that the output from this channel meets the pulse train requirements stated previously, and that the unit, when finally built and tested, constitutes a satisfactory source of pulses with the characteristics and requirements set forth earlier in this introduction.

Detailed Description of Channels:

Channel A. FREE RUNNING BLOCKING OSCILLATOR

This channel is composed of a single stage, ½5670, a high reliability, high frequency twin triode. Referring to drawing EA3, the triode is operated as a free running blocking oscillator, and is used as the master oscillator or timing reference for the entire unit. The pulses produced by this stage are very narrow, about .2 microsecond, and their frequency can be controlled. R_5, which is a 5 megohm potentiometer front panel control and C_5, a 100 micromicrofarad capacitor, determine the pulse repetition frequency. R_{26}, a 5.1 K resistor, is for the purpose of limiting the small grid current which tends to flow just before the tube blocks. The damping resistor R_{24}, 2.7 K, is used in the grid circuit to limit, somewhat, the overshoot after blocking occurs.

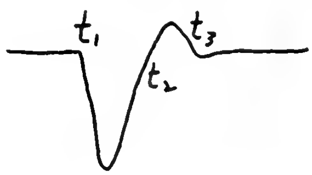


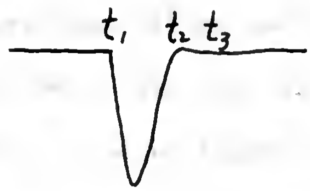
Plate waveform

Referring to the above sketch of the pulse waveform at the plate of the oscillator tube, the damping action is as follows:

Prior to t_1 the tube is in a cutoff state and the plate rides at B+, or about 260 volts positive. At t_1, the grid has recovered sufficient to bring the tube out of cutoff and into the conduction region. The plate potential then drops and the grid potential rises very rapidly due to the regenerative action of the pulse transformer. During this period, t_1 to t_2, the damping resistance, reflected into

the plate circuit as an impedance of the same value, due to the 1:1 turns ratio of the windings, is in parallel with the small dynamic plate resistance of the tube. The damping resistance then has only a small effect on the total swing of the plate and so attenuates the pulse amplitude only slightly.

During time t_2 to t_3, however, the situation is considerably modified. At time t_2 the tube is cutoff and the positive swing, or first overshoot, of the plate waveform is developed across the static plate resistance of the tube. As was the case from t_1 to t_2, this tube impedance, now very much larger than during conduction, is again shunted by the reflected impedance of the small damping resistor. Consequently, the amplitude of the positive swing is greatly reduced with the following output wave at the plate as a result.



By thus reducing the transient to negligible proportions, the pulse repetition rate can be made very high with no cross talk between successive pulses.

The output of the stage is a narrow positive pulse developed across the 100 ohm cathode resistor, R_{25}. It is coupled thru crystals Y_1 and Y_2, both Raytheon type CK708, to channels (B) and (C) respectively.

An interesting feature of the stage is the blocking oscillator transformer. This transformer consists of twelve turns on the primary, and the same number on the secondary, of #38 SSE wire, wound on a mandrel of 3/16" outer diamter. Complete instructions are given on page 48 for winding these coils. The coils are completely contained in a small pot core, see the figure on page which is mounted on a 1-1/8" X 5/8" piece of 3/32" glass silicone board. The electrical properties of this silicone glass laminate are very much superior to those of other types of rigid laminations for electrical applications and, in addition, this type board is characterized by high heat stability and low water absorption. The coil leads are terminated on turret terminal lugs, type 1724C, made by the Cambridge Thermionic Corporation. The turret type lug has two soldering spaces, permitting two or more connections without superimposing wires and assures good contact with neater connections and appearance. The lugs are of brass, heavily silver plated. This type of mounting is a necessity since the #38 wire size is too fine to allow good point to point soldering. The damping resistor is connected between the turret lugs, on which leads F1 and S1 are terminated, affording a sturdy mounting.

The Ferroxcube core employed is made from manganese zinc ferrites, pressed into shape and sintered to give considerable hardness to the element. The material is characterized by high initial permeability, low total losses (residual, eddy current, and hysteresis), high saturation flux density, and good temperature stability. The initial permeability is more than 15 times that of presently available powdered iron cores.

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Above 15 kc the hysteresis loses in a core are negligible in comparison with the eddy current losses. The resistivity of ferroxcube material is so very high that these eddy current losses are very small and any need for laminating the core is eliminated.

The above properties together with the enclosing type core used constitute a very effective pulse transformer. The high Q and permeability permit using a small number of turns, which leads to a very narrow pulse. The waveforms for this stage are shown on page 51.

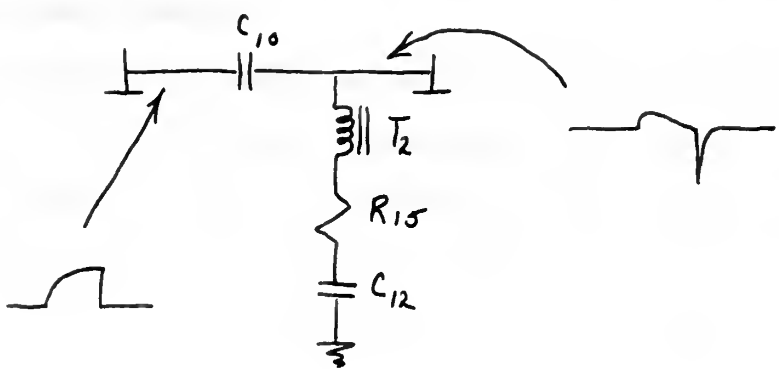
A sync output is also taken from this section. This is required when the stage is functioning at low pulse repetition rates. Under these conditions, after the tube has blocked, the grid potential approaches cutoff very gradually. As a result there is a considerable range, time wise, over which the tube might again conduct, any slight positive fluctuation in the recovering waveform, as cutoff is neared, being sufficient to cause the tube to again cycle. This results in a very small jitter which can only be overcome by using some means of syncing, such as a sine wave superimposed on the grid, to cause positive firing. However, since the sync output is used to "time control" the rf signal generator which this test unit modulates, the slight jitter effect is not apparent in the pulsed output of that generator.

Channel B. DELAY MULTIVIBRATOR & SLAVE BLOCKING OSCILLATOR

This channel generates a positive pulse which can be delayed over a range of several microseconds. Three stages are included in this channel, V_9 and V_{10} the two halves of a 6J6, constituting a one-shot delay multivibrator and V_{11}, a 6C4, a slave blocking oscillator. Referring to figure EA4, action of the circuit is as follows:

A positive pulse from channel (A) is coupled through C_8 to the grid of V_9. The fixed bias on this grid is such that this positive pulse is sufficient to cause V_9 to conduct. The action that follows is that of a typical one shot multivibrator. The output at the plate of V_{10} is a positive square wave. This wave is not coupled back thru C_7 and C_8 to the cathode of V_{13} because of the unidirectional nature of the crystal, Y_1, and hence does not interfere with the proper operation of channel (C). The width of this square positive pulse is variable and is controlled by potentiometer R_{30}, a front panel control, in the grid circuit of V_{10}.

The RLC network composed of C_{10}, the plate coil of T_2, R_{35} and C_{12} differentiates this positive square wave as shown in the accompanying schematic.



The negative spike (the differentiated after edge of the square pulse) serves to initiate action in stage V_{11}, the slave blocking oscillator. This tube is normally held in a non-conducting state by a fixed bias of about -27 volts on its grid. The output of this blocking oscillator is a positive pulse developed across R_{34}, 220 ohm. It is coupled out through a .01 capacitor to C_{13} and may be used to control pulse generation channels (D) through (H).

C_6, C_{12}, and C_{14} all serve as decoupling capacitors and so prevent modulation of either the B plus or the bias supplies. R_{32}, R_{28}, and R_{29} comprise a voltage divider network from plus 260 volts to minus 42 volts, providing a fixed bias of about -20 volts on the grid of V_9 under dynamic conditions. This keeps the tube well below cutoff and precludes the possibility of the multivibrator free running. This possibility of free running must be avoided since V_{11} will conduct very heavily in the event it occurs. R_{35} is a 1 watt resistor and will burn out quickly when so heavily overloaded. Under normal operation the duty factor is very small since V_{11} conducts only a fraction of a percent of the total time of a cycle and overdissipation in V_{11} and R_{35} is not then a factor for consideration.

Y_3, a CK708 crystal diode, is used for damping the overshoot in the grid circuit of the blocking oscillator. This method of damping is used in order to obtain the maximum amplitude of output signal. With resistance damping this is not the case.

The waveforms observed at salient points in channel (B) are shown on page 52. Attention is called to that waveform observed at the plate of V_9. The dotted line, $t_2 - t_3$, shows the expected wave form, the

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[illegible] ( ) are shown [illegible] 52. [illegible]

solid line the observed waveform. The absence of the predicated overshoot is due to the very large shunt capacity between the plate of V9 and ground.

Channel C. DELAY MULTIVIBRATOR, STRETCHING & SHAPING NETWORK, SLAVE BLOCKING OSCILLATOR & AUDIO AMPLIFIER

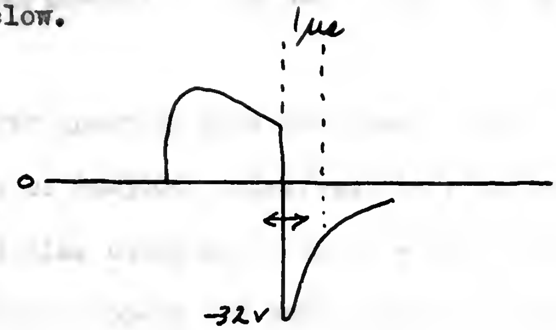
This channel, shown schematically on drawing EA5, produces a pulse about .2 microseconds wide which can be positioned in time over several microseconds and which can be wobbulated timewise about one-half microsecond either side of its unmodulated position. The wobbulation can be carried out over a frequency range of a few cycles up to several thousand cycles. Over this frequency range and excursion in time the modulation is essentially linear and has no discontinuities. This output pulse is used in the same manner as that from channel (B), to control pulse generation channels (D) through (H).

The entire channel (C) is made up of seven stages. V_1, and V_2 constitute a variable delay one-shot multivibrator. V_3 is a diode connected triode, ½5670, used for clipping. R38, C23, R46, and R49 constitute a pulse stretching and shaping (integrating and peaking) network. V_4 is an inverter - amplifier which is followed by V_5, an isolation stage cathode follower in which the leading edge of the pulse is further stretched. V6 is an audio amplifier with low frequency compensation to improve the response of the stage. V_7 is a slave blocking oscillator, normally biased below cutoff, controlled by the combined signals from V_5 and V_6 on its grid.

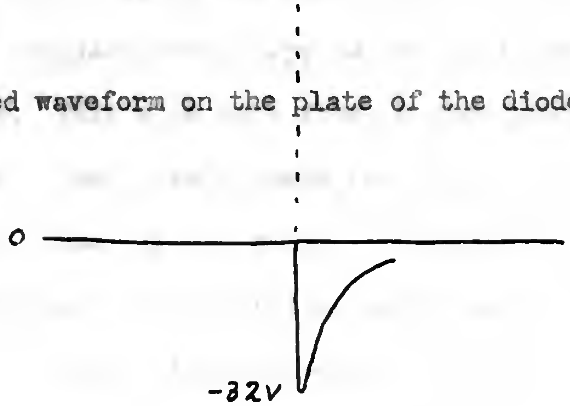
The complete operation of the channel is as follows:

A positive pulse about .2 microseconds wide and 45 volts in amplitude is coupled from channel (A) through C15 to the grid of V_1, the normally OFF section of the delay multivibrator. R43, R40, and R39 comprise a voltage divider network which biases V_1 below cutoff with about -30 volts on the grid. The output of the delay multivibrator is

a positive square wave at the plate of V_2, and the width (position of the trailing edge) of this pulse is controllable by varying R_2, a 500K potentiometer front panel control. This square wave is differentiated across the C_{22} - R_{48} combination. The diode V_3 passes only the negative pulse obtained from the differentiation of the trailing edge of the square wave. The differentiated pulse as appearing at the cathode of V_3 is shown below.



The clipped waveform on the plate of the diode is



The pulse is stretched from .2 microsecond to .4 microsecond by the charging of C_{23}, the stray or shunt capacitance from pin 3 of V_3 to ground. This leading edge is now the important factor for consideration. The negative pulse is developed across the R_{146} - R_{49} combination and a portion of it impressed on the grid of V_4. In this stage it is inverted and amplified and the leading edge of the plate waveform is stretched to about three microseconds. With a rise time of this duration the early portion is nearly linear. The integrated

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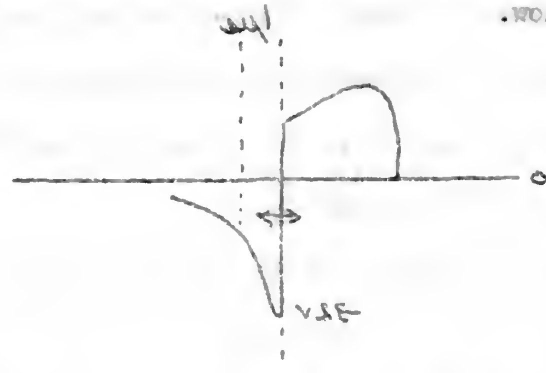

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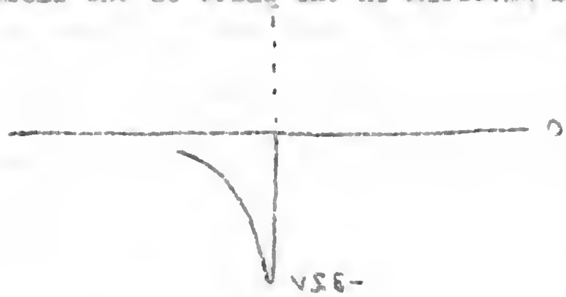

The pulse is stretched from .2 microsecond to .4 microsecond by the charging of C_{22}, the stray or shunt capacitance from pin 3 of V_3 to ground. This leading edge is now the important factor for consideration. The negative pulse is developed across the R_{46} - R_{47} combination and a portion of it impressed on the grid of V_4. In this [illegible] it is inverted and amplified and the leading edge of the plate [illegible]

wave is coupled via C_{24} to the grid of the cathode follower V_5. In the cathode follower stage the pulse is further stretched (integrated), a characteristic of such stages. The three microseconds rise time of the pulse on the cathode of V_5 is nearly uniform in its rate of rise. The positive pulse at the cathode of V_5 is coupled through capacitor C_{26} to the grid circuit of the slave blocking oscillator stage, V_7. This waveform is superimposed on the d-c fixed bias on the control grid of this stage.

An audio input is also provided in this channel. The audio source, a sine wave of 20-3000 cycles/sec, is a Hewlett Packard 202D audio oscillator or similar equipment. V_6 is a low frequency compensated audio amplifier which boosts the audio input in amplitude, after which the signal is coupled through C_{27} to the grid circuit of the slave blocking oscillator. This sine wave form is then superimposed upon the dc fixed bias, also. The three signals (d-c bias, pulse, sine wave) then combine to determine the time at which V_7 will cycle.

Referring to figure (A) on page 15a, the static conditions are seen to be such that the slave blocking oscillator is biased below cutoff. In this state there is a zero output from the channel. Figure (B) shows the positive pulse with a sloping leading edge which is coupled through C_{26} to the grid circuit of V_7 from V_5. This pulse combines with the dc bias to give the wave shape of figure (C). Now, it can be seen that at time t_3 the combined signals add to a value which pushes the potential on the grid out of cutoff. At this time, then, the tube conducts, blocks, and completes a cycle with a positive pulse about .2 microsecond wide being developed across R_{47}, the 100 ohm cathode resistor. This pulse and that at the grid are shown on page 53, Waveforms for Channel (C).

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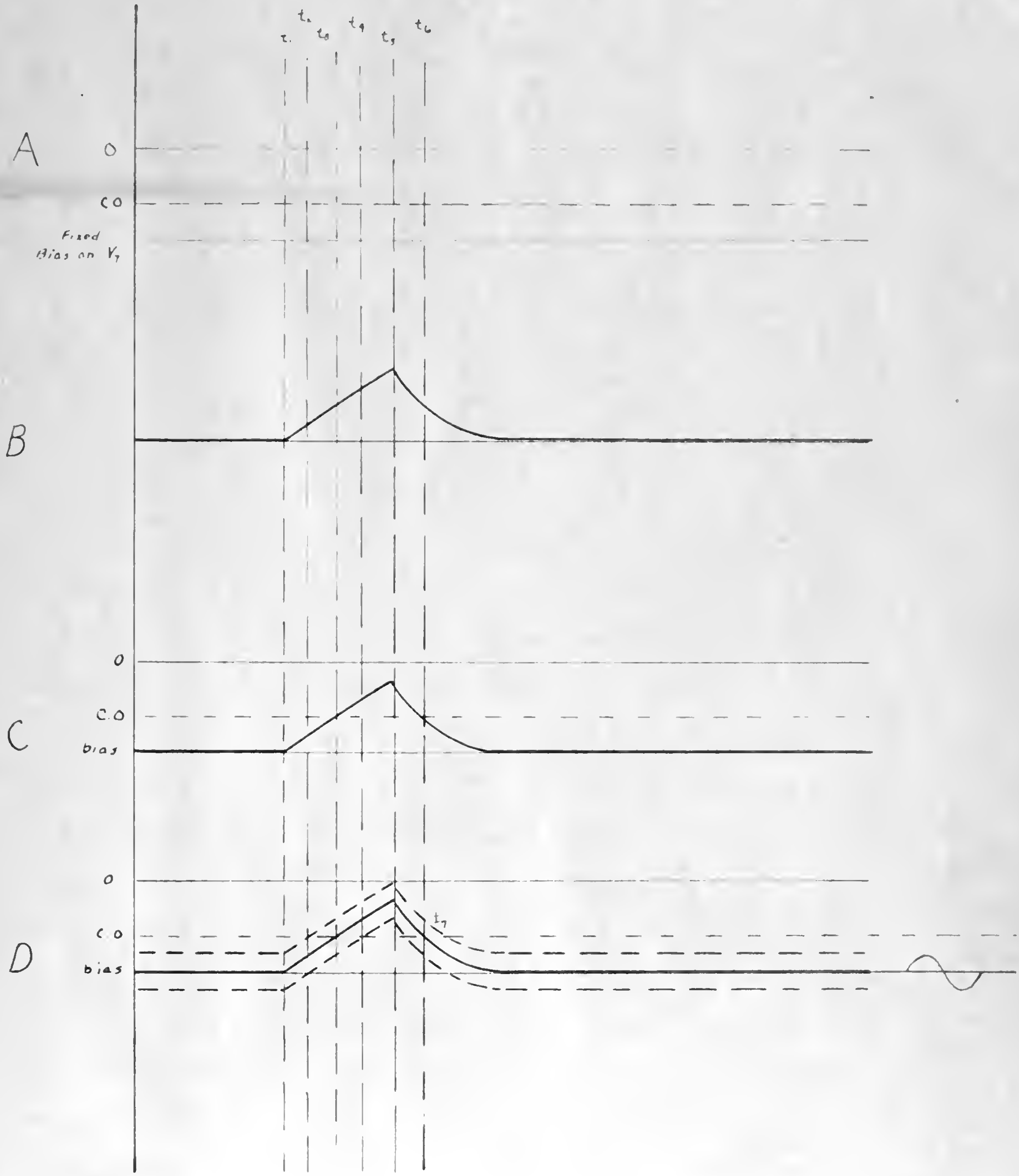
A
0
C O
Fixed
Bias on V_7
B
0
C.O
C
bias
0
C.O
D
bias

If only the fixed d-c bias of about -20 volts and the positive pulse from V_5 were present in the grid circuit of V_7, the tube would fire once each time the positive pulse arrive. The recovery time of the stage is sufficient to prevent another cycle being initiated in the time period of t_3 to t_6 when below cutoff conditions are not present. The recovery time actually is such that, at some later time t_7, a cycle could occur if the grid potential were raised above the cutoff point.

The audio frequency sine wave injected into the grid circuit from the audio amplifier stage V_6 modifies the times of firing indicated above. This wave, shown at the right in figure (D), has a frequency very much smaller than that of the positive pulse of figure (B). The d-c fixed bias can be considered to be slowly modulated, toward and away from the cutoff level, by this audio frequency signal. Referring to figure (D), left hand portion, the effect of this sine wave modulation is seen to be on the firing time for the tube V_7. As the sine wave increased positively, the firing time is advanced from t_3 to t_2 (upper dotted waveform). When the sine wave swings to its negative extreme the firing time is delayed to time t_4. Recalling that many positive pulses occur during a single sine wave, the firing time is seen to vary sinusoidally from t_3 to t_2, back to t_3, to t_4, and back again to t_3 during a single audio cycle. The degree of linearity with which this variation of firing time occurs is a function of the uniformity of the slope, or rate of rise, of the leading edge of the positive pulse. Controls R3 (coarse) and R4 (fine) are used to adjust the fixed d-c bias so that firing occurs during the earlier, more linear, portion of the positive pulse's leading edge. Care must be

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[illegible]

taken, however, that time t_3, figure (C), is not advanced so much that t_2, figure (D), would tend to occur before t_1. Under such conditions the oscillator would free run and no control would be exercised over the stage during this t_2 to t_1, period.

The slave blocking oscillator itself is conventional and nearly identical with the one in channel (B). The positive, wobbulated, output pulse developed across R_{47} is coupled through C_{20} to a single pole double throw selector switch, where it may be selected to control pulse generation channels (D) through (H).

Channels (D) through (H). CATHODE FOLLOWER, DELAY MULTIVIBRATOR, SLAVE BLOCKING OSCILLATOR, CATHODE FOLLOWER

Channels (D), (E), (F), (G), and (H) are identical in circuitry and function. In describing the actions of these channels reference will be made only to drawing EA6, Channel (D) of Modulator. For building and identifying components in the other pulse generation channels a cross-reference table is included, see pages 46 and 47.

Action in pulse generation channel (D) is inaugurated by a fixed positive pulse selected from channel (B) by switch S_3, or by a positive pulse wobbulated timewise at an audio frequency selected from Channel (C) by the same switch, S_3. This positive pulse, fixed or wobbulated, is coupled through isolation cathode follower V_{43} to the grid of V_{14}, the normally OFF half of the variable delay multivibrator V_{14}-V_{15}. The grid of V_{14} is maintained below cutoff potential by a fixed d-c bias of -27 volts.

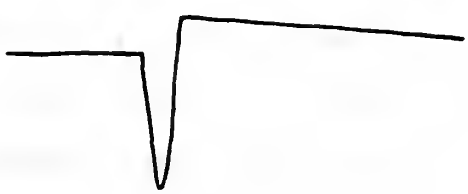
The output of this multivibrator is a positive square pulse appearing at the plate of V_{15}. The width of this pulse, i.e. the after edge, is variable using potentiometer R_7 on the front panel. This square wave is differentiated in the circuit of C_{48} and the plate coil of T_4. The negative pulse, resulting from differentiating the after edge causes the slave blocking oscillator to cycle. A positive pulse, .2 microsecond wide, is developed across the 100 ohm cathode resistor, R_{84}. This signal is coupled through a cathode follower, V_{17} for purposes of isolation, and thence to crystal diode Y_{12}.

Channel K. INVERTER AMPLIFIERS AND CATHODE FOLLOWERS

In this, the final channel, the five positive pulses generated in pulse generation channels (D) through (H) are combined, amplified and coupled to BNC output connectors through isolation stages.

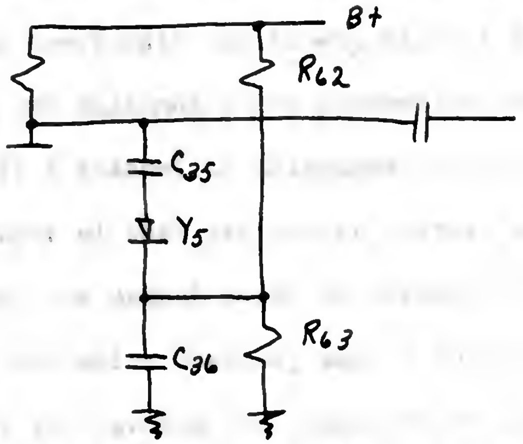
Referring now to figure EA7 and the waveforms for channel (K), a series of five pulses is coupled through C_{32} to the control grid of V_{41}, a fairly high g_m, high efficiency power pentode operated as a class A amplifier. This tube is of miniature construction and is characterized by low interelectrode capacitances and high perveance, so is well adapted to high frequency and wide band service. R_{58} and R_{59} form a voltage divider network which provides a fixed bias of -30 volts. By so operating the stage, (fixed bias) the effect of degeneration, present with grid leak or cathode bias, is avoided and greater gain is obtained.

Without some means of limiting, the waveforms at the plate of this stage are as shown below (considering a single pulse):



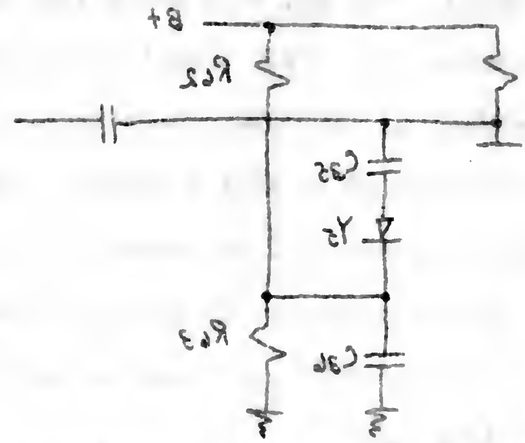
When several pulses, closely spaced are present, each pulse rides in the combined overshoots of those pulses preceding it and the effect indicated below results:

The grid pulses are clean, so the transient is the result of the discharge of stray capacitances in the plate circuit. By using the network below this objectionable effect is eliminated:

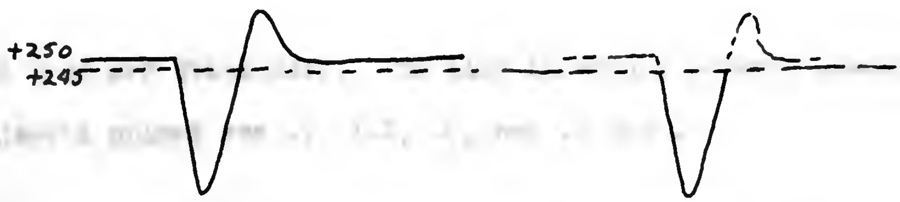


The plate of the tube is normally at about 250 volts. Voltage divider network R62 and R63 maintains the lower end of the crystal, a CK708, at about 245 volts. The crystal, being a unidirectional device, is arranged so that a positive pulse will be passed from the upper to the lower end (as located in the above drawing). With the circuit elements connected in this manner, whenever the plate of V_{41} is more positive than about 245 volts the crystal presents a low impedance of approximately 350 ohms, and so very effectively clips the overshoot. This is demonstrated in the sketch following:

The grid pulses are clean, so the transient is the result of the discharge of stray capacitances in the plate circuit. By using the network below this objectionable effect is eliminated:



The plate of the tube is normally at about 250 volts. Voltage divider network R62 and R63 maintains the lower end of the crystal, a CK708, at about 245 volts. The crystal, being a unidirectional device, is arranged so that a positive pulse will be passed from the upper to the lower end (as located in the above drawing). With the circuit elements connected in this manner, whenever the plate of V_{11} is more positive than about 245 volts the crystal presents a low impedance of approximately 350 ohms, and so very effectively clips the overshoot. This is demonstrated in the sketch following:



Before following the pulses on through the remainder of Channel (K), mention should be made of the flexibility of the pulse train.

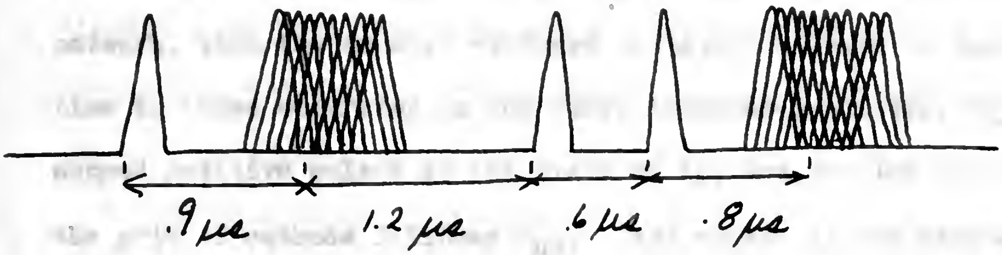
As previously explained, each of these five pulses is generated in its own distinct pulse generation channel, channels (D) through (H). If a channel is triggered by the fixed pulse from channel (B), the output of that particular channel will be a fixed pulse. If, instead, the output pulse of channel (C) is used for triggering a pulse generation channel, and if an audio signal is being fed into channel (C) causing its output to be frequency modulated, then the output pulse of that pulse generation channel will also be frequency modulated (wobbulated in time).

Depending on the position of switches SW_3 through SW_7, the train of five pulses which is coupled to grid 1 of V_{41} may be constituted of any combination of fixed or wobbulated pulses. The pulses may be positioned relative to each other by controls R_7, R_9, R_{10}, R_{11}, and R_{12}. Furthermore, all pulses in the train which are produced through action of the trigger pulse from channel (B) can be postioned simultaneously by control R_{30}. The same is true for pulses generated in channels triggered from channel (C), control in time here being effected by R_2. As an example, in the accompanying figure a typical pulse train is drawn. The second and fifth pulses are shown being wobbulated at an audio rate, say 1000 cy/sec. Pulses one, three,

Before following the pulses on through the remainder of channel (F), mention should be made of the flexibility of the pulse train. As previously explained, each of these five pulses is generated in its own distinct pulse generation channel, channels (D) through (H). If a channel is triggered by the fixed pulse from channel (B), the output of that particular channel will be a fixed pulse. If, instead, the output pulse of channel (C) is used for triggering a pulse generation channel, and if an audio signal is being fed into channel (C) causing the output to be frequency modulated, then the output pulse of that pulse generation channel will also be frequency modulated (wobbulated in time).

Depending on the position of switches SW_3 through SW_7, the train of five pulses which is coupled to grid 1 of V_{11} may be constituted of any combination of fixed or wobbulated pulses. The pulses may be positioned relative to each other by controls R_7, R_9, R_{10}, R_{11}, and R_{12}. Furthermore, all pulses in the train which are produced through action of the trigger pulse from channel (B) can be positioned simultaneously by control R_{20}. The same is true for pulses generated in [illegible] channel (C), control [illegible] [illegible] of- [illegible] as an example, [illegible] accompanying [illegible] a typical [illegible] being [illegible]

and four are stationary. The time intervals between leading edges of adjacent pulses are .9, 1.2, .6, and .8 usec.

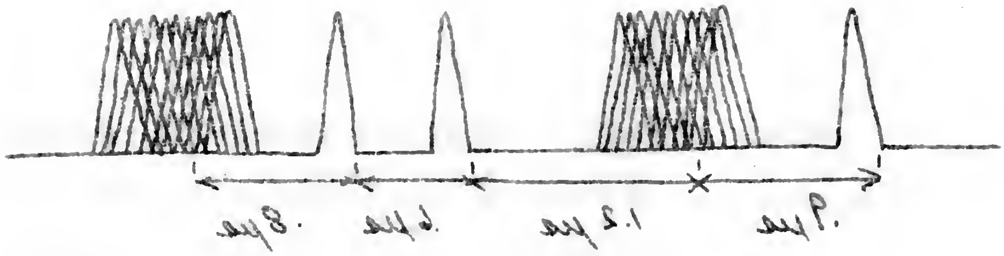


This pulse train is inverted and amplified by V_{41}, shaped by the crystal network and coupled into cathode follower V_{48} for isolation purposes. The pulses on the grid of the cathode follower are negative. If these waveforms are to appear on the cathode of this stage, the grid must be maintained at a positive potential of such magnitude that the tube is not cutoff by the negative input pulses, since this would result in unwanted clipping and distortion of the pulses.

A voltage divider composed of R_{64} and R_{65} furnishes a positive bias of 125 volts under dynamic conditions. This maintains the grid at a proper level to prevent grid clipping. Considerable grid current is drawn, of course, and this injects a grid leak bias into the circuit for consideration. The plus 125 volts desired, and obtained, is the result of fixed plus grid leak bias and, as noted above, is the condition prevailing when the equipment is in operation.

The negative pulse developed across R_{66} is coupled through C_{39} to the BNC fitting on the front panel labeled NEG. OUT. The capacitor C_{39} serves to prevent the tube from burning out in the event a d-c short to ground is placed across the output terminals.

and four are stationary. The time intervals between leading edges of adjacent pulses are .9, 1.2, .6, and .8 usec.



This pulse train is inverted and amplified by V_{11}, shaped by the crystal network and coupled into cathode follower V_{12} for isolation purposes. The pulses on the grid of the cathode follower are negative. If these waveforms are to appear on the cathode of this stage, the grid must be maintained at a positive potential of such magnitude that the tube is not cutoff by the negative input pulses, since this would result in unwanted clipping and distortion of the pulses.

A voltage divider composed of R_{64} and R_{65} furnishes a positive bias of 125 volts under dynamic conditions. This maintains the grid at a proper level to prevent grid clipping. Considerable grid current is drawn, of course, and this injects a grid leak bias into the circuit for consideration. The plus 125 volts desired, and obtained, is the result of fixed plus grid leak bias and, as noted above, is the condition prevailing when the equipment is in operation.

The negative pulse developed across R_{66} is coupled through C_{39} [illegible]. The capacitor [illegible]

A small portion of the negative pulse appearing at the cathode of V_{48} is coupled to the grid of V_{47}, another 6AN5 inverter-amplifier. This stage is also equipped in the plate circuit with a pulse clipping network, with the crystal reversed to handle signals of opposite polarities to those occurring in the first inverter-amplifier, V_{41}. The shaped positive pulses at the plate of V_{47} are coupled through C_{41} to the grid of cathode follower V_{49}. They appear at the cathode of the same tube and are coupled through a d-c isolation capacitor, C_{40}, to the BNC fitting on the front panel labeled POS. OUT.

POWER SUPPLY

The power supply for the subject unit is included as an integral part of that unit. However, the chassis on which it is built can be disconnected from the main chassis merely by breaking the 14 wire connector plug between the two units and removing the fastener bolts holding the two chassis together.

The power supply furnishes plus 260 volts for plate supply and a -42 volt supply for biasing purposes. It also furnishes a filament supply of 6.3 volts, and, although not at present connected to the coupling plug, could furnish a 5 volt filament supply.

The high voltage transformer is a Stancor Universal Type, #P-6314. The plate or secondary furnishes 700 volts, center tapped, at 200 mils. Two filament winding supply 5 volts, center tapped, at 3 amps and 6.3 volts, center tapped, at 5.5 amps. The transformer weighs about 7.7 pounds and has a mounting area of 4.5" X 3.75".

The total filament current drain exceeds the 5.5 amp rating so a separate filament transformer is employed. This transformer is a Stancor Single Secondary Type, #P-6308. The secondary supplies 6.3 v, center tapped, at 10 amps which exceeds somewhat the total filament drain. This filament drain is about 9 amps. The transformer weighs about four pounds and requires a mounting area of 2.8" X 3.2".

Several other equivalent transformers are available commercially and may be substituted if those listed above are unavailable. The P-6314 may be replaced by a Chicago Cat. #PH-200, or U.T.C. Cat. #R-109, or a Thordarson Cat. #T-22R07. The P-6308 has an equivalent in a Chicago Cat. #F-610, a U.T.C. Cat. #CG-122 or an S-61, and a

Thordarson Cat. #T-21F12.

For rectification, three 6X4 full wave rectifiers are connected in parallel. These miniature tubes have a max. dc output current handling capacity of 70 ma a piece or 210 ma for the parallel combination.

A pi type C-L-C smoothing filter is employed. The capacitors used are 40 microfarad, plug in type (using octal socket) electrolytics, rated at 450 working volts.

The single filter choke in the network is a Stancor Heavy Duty Type, #C-1721, 8.5 henries and rated at 200 ma. Its d-c resistance is 120 ohms, weight about 4 pounds and mounting dimensions 3.2" x 3.3". Other commercial equivalents are Chicago Cat. #RC-8200 and Thordaraon Cat. #T-20C55, 56.

A 6AS7G, low mu twin power triode is used as a current control tube. This glass octal tube is the only non-miniature employed in the entire unit. The current handling capacity is 125 ma per section. The bias control tube is a 6AK5 sharp cutoff pentode. An OA2 glow-discharge diode is used, for a 150 volt voltage regulator. A divider network, R_{15} and R_8, provides bias control for the 6AK5. The positive and negative output voltages are taken off across R_{18} and R_{20} respectively, a bleeder network.

In detail the regulated power supply functions as follows:

The 115 volt ac input voltage is stepped up by T_9 to 700 volts. The secondary is center tapped so that 350 volts (rms) is applied across each section of the full wave rectifiers. The two halves of the rectifiers conduct alte nately as each plate is made positive by the secondary of the transformer. The capacitors C_1 and C_2 charge

when the rectifiers conduct and discharge through the bleeder network when the tube is not conducting. The choke tends to keep a constant current flowing in the same direction through the load, due to the build-up and collapse of its magnetic field when the current increases and decreases.

The voltage (d-c) at the positive end of C_1 is 400 volts when the equipment is in full operation. The potential across C_2 is 375 volts. This means a drop of 25 volts occurring across the choke, L_1.

The current being drawn is then

25v/120 ohms = 208 ma.

This current is divided three ways between the 6X4's, i.e. 69 ma per tube. The drop across the rectifiers is

69 ma x 150 ohms = 10.4 volts.

The 150 ohms is the approximate total effective plate supply impedance per plate for the rectifiers.

The capacitor input to the filter is used to obtain a somewhat higher output voltage. The output voltages of the regulator are developed across the bleeder network R_{18} and R_{20} in parallel with the R_{15}-R_8. R_{18} is also paralleled by the resistance of the load. All the load current must also flow through the plate to cathode resistance of V_{38}, the current control tube. All the other elements in the regulator circuit function to control this resistance of V_{38} and thereby maintain a constant load voltage.

The plate supply voltage of V_{39} is the regulated output, i.e. about 260 volts with respect to ground (or 302 volts with respect to the center tap of the secondary).

when the rectifiers conduct and discharge through the bleeder network when the tube is not conducting. The choke tends to keep a constant current flowing in the same direction through the load, due to the build-up and collapse of its magnetic field when the current increases and decreases.

The voltage (d-e) at the positive end of C_1 is 400 volts when the equipment is in full operation. The potential across C_2 is 375 volts. This means a drop of 25 volts occurring across the choke, L_1.

The current being drawn is then

25v/120 ohms = 208 ma.

This current is divided three ways between the 6X4's, i.e. 69 ma per tube. The drop across the rectifiers is

69 ma x 150 ohms = 10.4 volts.

The 150 ohms is the approximate total effective plate supply impedance per plate for the rectifiers.

The capacitor input to the filter is used to obtain a somewhat higher output voltage. The output voltages of the regulator are developed across the bleeder network R_{14} and R_{16} in parallel with the R_{15}-R_3. R_{16} is also paralleled by the resistance of the load. All the load current must also flow through the plate to cathode resistance of V_{13}, the current control tube. All the other elements in the regulation circuit function to control this resistance of V_{13} and thereby maintain a constant load voltage.

The plate supply output is applied to the regulated output, i.e. at 150 [illegible] [illegible] [illegible] 3.2 volts [illegible] [illegible] [illegible] [illegible].

The bias on V_{39} is set by R_8 and so controls the current flow through the 6AK5. This current flows through R_{13}, an 82K plate resistor, causing a drop across it. This drop is the bias on V_{38}. Hence, the adjustment of R_8 establishes the normal plate resistance of V_1. This adjustment is used to set the desired value of load voltage which the regulator is to maintain, in this case plus 260 volts.

Any tendency for the load or output voltage to drop tends to increase the bias on V_{39}. This results directly in a lower bias for V_{38}, which in turn means a lowering of the plate resistance of this tube. A smaller portion of the available voltage then appears across the tube and so the output load voltage remains practically constant.

The pentode is used for V_{39} because small variations in the load voltage are amplified sufficiently to insure proper operation of the regulator circuit.

To insure that the glow tube V_{34} will ionize when the power supply is first turned on its anode is connected through R_{14} to the plate of V_{39}.

The bleeder network in this regulator actually serves two purposes. It acts as a discharge path for the capacitors when power is removed, and it acts as a stabilizer to protect the voltage regulator at no load.

The bleeder current is

$$\frac{260v}{11.2K} = 23.2 \text{ ma}$$

which is about 11% of the total current.

Dissipation in R_{18} is

$$(.0232^2)\ (11200) = 6.3 \text{ watts}$$

The total current flows through R_{20}. Across the resistance, -42 volts is developed, therefore its value is

$$\frac{42v}{208\ ma} = 202 \text{ ohms}$$

A twenty-watt, 500 ohm, wirewound resistor with a variable tap is used here and adjusted to the proper value of 202 ohms.

Plate dissipation in V_{38} is

$$(375 - (260 \text{ plus } 42)) \times .208 = 15.1 \text{ watts}$$

which is slightly above the rated max.

The cutoff or series resonant frequency for one LC section of the filter is

$$fc = \frac{1}{2\pi\sqrt{LC}} = 8.62 \text{ cy/sec.}$$

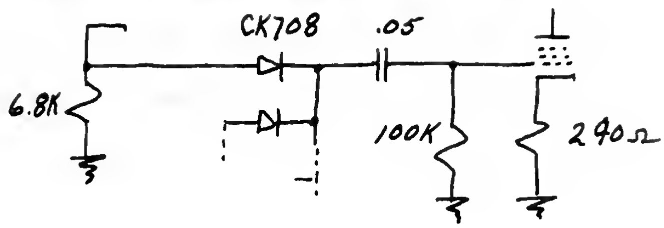
The ripple voltage is $E_c \simeq f_c^2/f_0^2$ where $f_0 = 120$ cy/sec for a full wave rectifier. This gives a ripple voltage of $\left[\frac{8.62}{120}\right]^2 = 5.16 \times 10^{-3}$ or the ripple voltage is .516% of the input voltage.

COMMENTS AND OBSERVATIONS

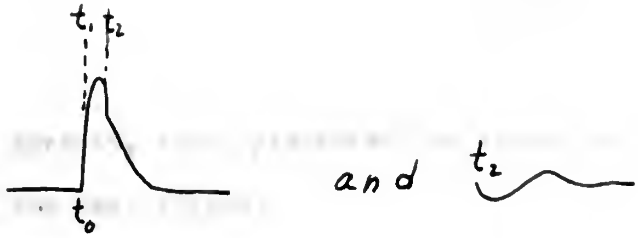
One of the most interesting and more difficult problems encountered in the design of this modulator unit occurred during work on the mixer section, Channel (K).

Clean positive pulses with no visible transients were obtained at the cathodes of V_{17}, V_{21}, V_{25}, V_{29}, and V_{33} the output cathode follower stages of channels (D), (E), (F), (G), and (H) respectively. These positive going signals were transmitted through the unidirectional crystals Y_{12} through Y_{16} (one per channel) and, depending upon the settings of the delay controls in the delay multivibrator in each channel, a coded pulse train was obtained such as that in the accompanying figure,

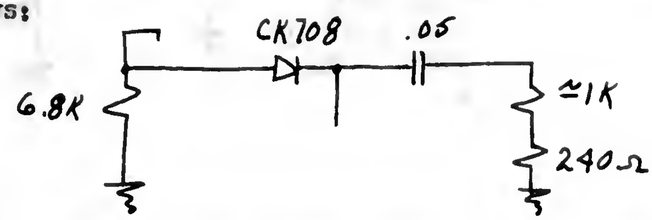
when observed at the forward end junction of the five CK708 crystals. The circuit involved was as follows:



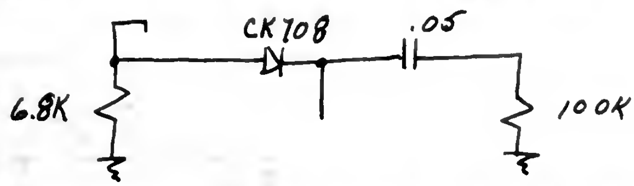
The wave shape could be broken down into, say, a stretched pulse with a long decay time plus a transient superimposed on the decaying trailing edge, i.e.



In the period from t_0 to t_2 the pulse shape was preserved. During the period t_1 to t_2 grid conduction occurred and the equivalent circuit was as follows:



which gave a fairly small RC decay time. However, as soon as the signal fell to where grid conduction ceased, the equivalent circuit became

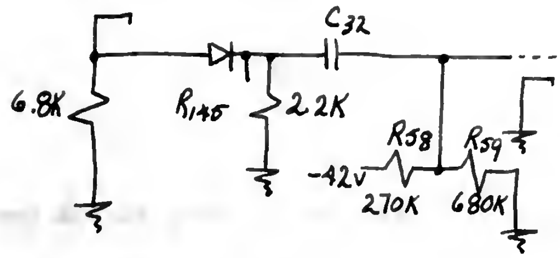


and the RC was increased over ten fold. The transient which occurred when the abrupt switch from grid conduction to non-conduction took place appeared as a natural result of the lead inductance in series with the coupling capacitance which form a series LC circuit. The high 100K damping resistance in the network prevented it from reaching any sizeable proportions.

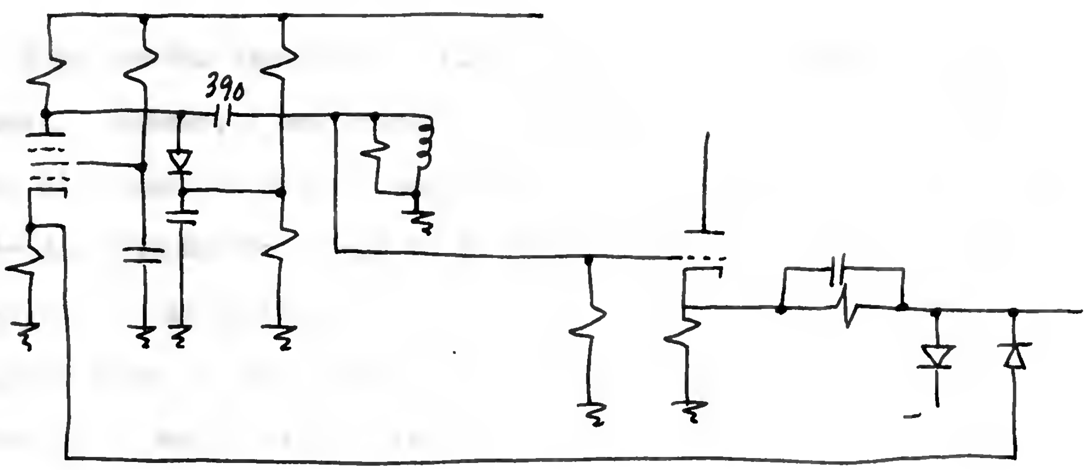
To correct these conditions and so preserve the waveform as developed across the 6.8K cathode resistor, several changes were made.

The long RC time constant was reduced by replacing the .05 capacitor with a .001 and a direct d-c discharge patch (2.2K to ground) included. Fixed bias replaced grid lead bias on the pentode amplifier and all leads were shortened as much as possible.

The new circuit, which preserved the waveshape very closely was as indicated in the next figure:



The first plate circuit for V_{41} built up on a breadboard was the following one:



The 390 micromicrofarad coupling capacitor was selected to series resonate with the peaking coil. The damping resistance across this coil was adjusted so that a waveform such as

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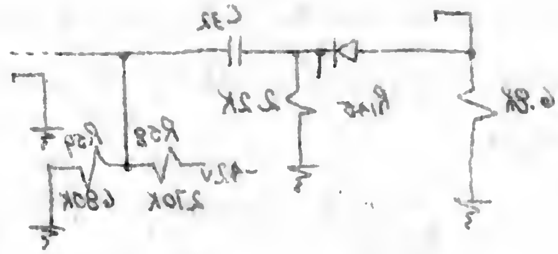

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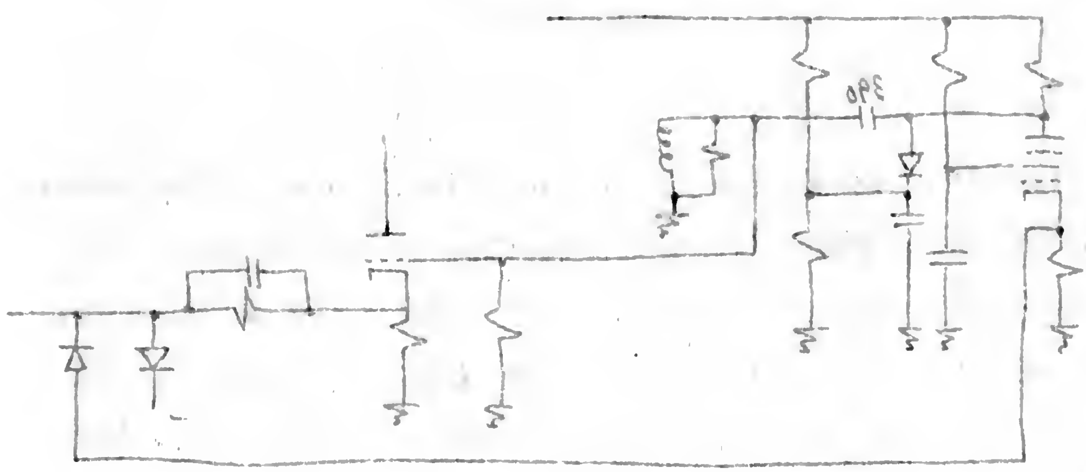

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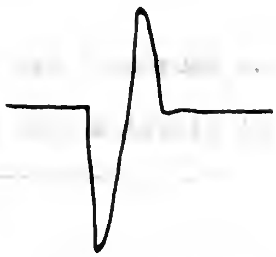
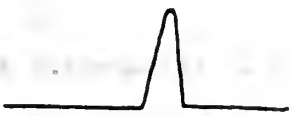
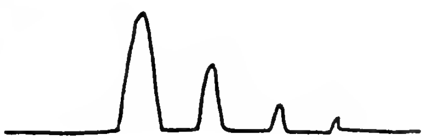
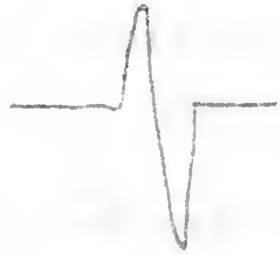


was obtained at the grid of the cathode follower. With the double limiting network in the output circuit of this cathode follower, a satisfactory positive pulse was obtained.



This was the case when a single pulse was put through the mixing channel. However, a new situation developed when the whole coded train of pulses was coupled through. It was now found that, when one pulse was brought very close to an adjacent one, the positive overshoot, which ultimately becomes the output pulse, rode down into the negative swing of the following pulse and its amplitude was greatly attenuated. And, as all pulses were brought into proximity and the negative swings were compounded, the output pulse train from the cathode follower took on this appearance:





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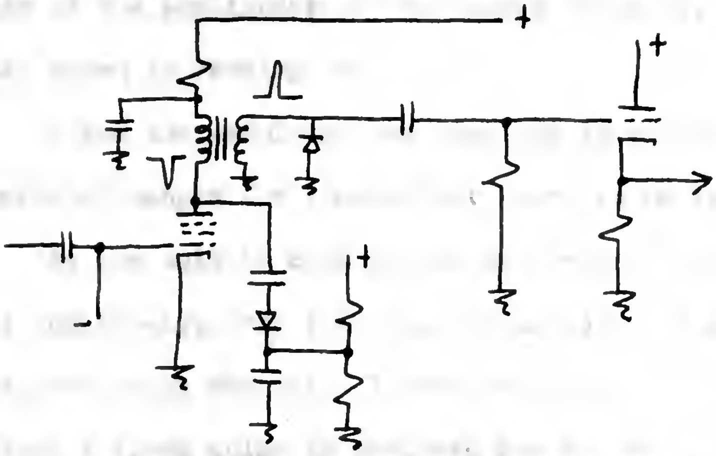
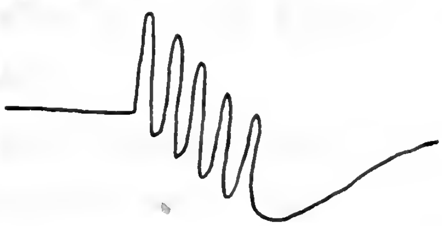
This arrangement was discarded as obviously unsatisfactory and a new circuit, as shown schematically in the next figure, was built:



In this circuit a step-up was obtained in the pulse transformer in the pentode plate circuit. The crystal diode in the secondary clipped any negative overshoot and the crystal network in the primary kept transients from appearing on the pulse developed at the plate of the pentode.

The output pulse train coupled to the cathode follower had the following appearance.



By varying the turns ratio of the pulse transformer, for details of which see drawing EA3, it was found that the remanance of the Ferroxcube core was sufficient, when a step up of 2:1 or greater was employed, that a "following" pulse occurred before the recovery time (of the core) was reached for a "preceding" pulse. Consequently, again there was the problem of one pulse introducing cross-talk upon another. A great many

turns ratios, wire sizes, core sizes, etc. were tried before it was found more satisfactory to get away from the cores entirely, due to the size of the amplitudes of the pulses involved. The ultimate circuit is that shown in drawing EA7.

Since the modulator has been completed and has been used, several possible changes for improvement have become apparent.

As the unit is constructed at present there is no means for cutting out completely, from the output coded pulse train, the pulse from any one particular channel. In one position of the single pole double throw switch a fixed pulse is produced and in the other position a wobbulating pulse is obtained. By replacing these two position toggles with types incorporating an OFF position, this undesirable condition can be rectified. Due to the circuit location of these switches no snuffer type contact mechanism, for eliminating pitting caused by arcing, is needed. A slow make, slow break type switch will allow decided economies over those switches designed for universal or d-c applications. The General Cement Mfg. Co., is one source of supply for this neutral center switch; Item #1308.

The power supply built for use with this unit utilizes a type 6AS7G as a current regulator in the stabilizing circuit. This is a rather large and unwieldy tube in a unit in which all other tubes are of miniature construction. This 6AS7G envelope protrudes even beyond the transformers and chokes used in the power supply. A new tube very recently brought out by the RCA Victor Division of the Radio Corporation of America is the type 6080. The 6080 is a low-mu, high perveance, twin power triode designed primarily for use as a regulator tube in

turns ratios, wire sizes, core sizes, etc. were tried before it was found more satisfactory to get away from the cores entirely, due to the size of the amplitudes of the pulses involved. The ultimate circuit is that shown in drawing SA7.

Since the modulator has been completed and has been used, several possible changes for improvement have become apparent.

As the unit is constructed at present there is no means for cutting out completely, from the output coded pulse train, the pulse from any one particular channel. In one position of the single pole double throw switch a fixed pulse is produced and in the other position a wobbulating pulse is obtained. By replacing these two position toggles with types incorporating an OFF position, this undesirable condition can be rectified. Due to the circuit location of these switches no special type contact mechanism, for eliminating sparking caused by arcing, is needed. A slow make, slow break type switch will allow decided economies over those switches designed for universal or d-c applications. The General Electric Co., is one source of supply for this neutral center switch, Type [illegible].

The power supply built for use with this unit utilizes a type [illegible] as a current regulator in the stabilizing circuit. This is a rather large and unwieldy tube [illegible] stabilizing [illegible]. This [illegible] [illegible] [illegible]

stabilized d-c power supply units. It is similar to the 6AS7-G in characteristics, but is smaller in size and features conservative ratings.

In d-c amplifier applications, maximum ratings for each unit include a plate voltage of 250 volts, plate current of 125 ma and a plate dissipation of 13 watts. These ratings are identical with those for the 6AS7G.

Another feature which might be changed, and so improve the unit, is the replacement of all 6J6 twin triodes by 5670's. This would reduce the types of tubes employed by one. The two types are similar except that the 6J6 employs a common cathode whereas each section of the 5670 has a separate cathode pin making this tube somewhat more versatile than the 6J6. This change would necessitate some readjustment of component values in the multivibrator circuits where the 6J6 is most frequently utilized.

Along this same line of thought it is noted that the tube V_6 uses ½6J6 and the other half of this envelope is unused. Also V_{13} utilizes half of envelope X_{12} while the other half is idle. This offers an opportunity for reducing the tube complement by one.

In the power supply the degree of regulation was sufficient to meet requirements of the unit. However, the margin was not great. In order to increase the sensitivity of the regulator to load changes, it may be desirable that a bias control tube, V_{39}, with a greater amplification than that afforded by the 6AK5 should be employed.

One final note about the power supply: It is generally regarded as more satisfactory to use both halves of a rectifier for the same phase and connect them thus,

stabilized d-c power supply units. It is similar to the 5487-6 in characteristics, but is smaller in size and features conservative ratings.

In d-c amplifier applications, maximum ratings for each unit include a plate voltage of 250 volts, plate current of 125 ma and a plate dissipation of 13 watts. These ratings are identical with those for the 6AS7G.

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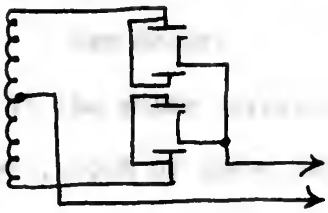
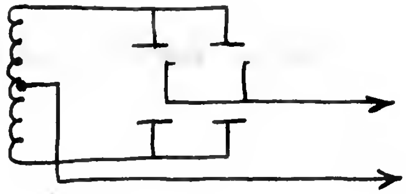
One final note about the power supply. It is generally regarded as more satisfactory to use [illegible] in a rectifier for the same type and connect them [illegible].



rather than



However, this requires an even number of rectifier tubes and would involve increasing the tube complement by one.

The CK708 germanium crystal diodes used in numerous circuits throughout the design are a Raytheon product. Their important characteristics are as follows:

Max. d-c inverse voltage	100 v
Peak anode current	100 ma
Max. ave. d-c anode current	35 ma
Min. fwd. current at +1 volt	3 ma
Max. inverse current at -100 volts	.625 ma
Shunt capacitance	1 mmf

There are a number of other germanium diodes available with about the same characteristics. Among these are:

1N38	Sylvania
1N38	Kempton
1N52	General Electric

Germanium when compared with other semi-conductors used in point contact type diodes possesses the following advantages:

1. The ability to withstand a much higher inverse voltage.

2. The ability to self-heal in cases where electrical breakdown may occur.

In the pulse transformer applications to which these crystal diodes are put, both of these advantages are an asset.

Summary of Front Panel Controls

Type Control	Labeled	Item No.	Function
Pot.	Reg	R_8	Set regulated voltage
Pot.	Fixed (B)	R_{30}	Delay Fixed Pulses
Pot.	Wob (C)	R_2	Delay Wob. Pulses
Pot.	Coarse	R_3	Adjust bias
Pot.	Fine	R_4	Adjust bias
Pot.	Rep (A)	R_5	Control rep. rate
BNC	Sync Out		
Toggle	Fix-Wob	SW_3	Select Type Pulse
Toggle	Fix-Wob	SW_4	Select Type Pulse
Toggle	Fix-Wob	SW_5	Select Type Pulse
Toggle	Fix-Wob	SW_6	Select Type Pulse
Toggle	Fix-Wob	SW_7	Select Type Pulse
BNC	Audio-In		
Pot.	Chan. D	R_7	Delay Pulse
Pot.	Chan. E	R_9	Delay Pulse
Pot.	Chan. F	R_{10}	Delay Pulse
Pot.	Chan. G	R_{11}	Delay Pulse
Pot.	Chan. H	R_{12}	Delay Pulse
Receptacle	115 v a-c		
Toggle	Fil.	SW_1	Operate Fil. Xfmr
Toggle	H.V.	SW_2	Operate H.V. Xfmr
BNC	Neg. Out		
BNC	Pos. Out		

Vacuum Tube Summary

Tube	Type	Channel	Function
V_1	$\frac{1}{2}$6J6	C	Delay Multivibrator
V_2 (X_1)	$\frac{1}{2}$6J6	C	Delay Multivibrator
V_3	$\frac{1}{2}$5670	C	Diode Clipper
V_4 (X_3)	$\frac{1}{2}$5670	C	Inverter-Amplifier
V_5	$\frac{1}{2}$5670	C	Cathode Follower
V_6	$\frac{1}{2}$6J6	C	Audio Amplifier
V_7	6C4	C	Slave Blocking Oscillator
V_9	$\frac{1}{2}$6J6	B	Delay Multivibrator
V_{10} (X_9)	$\frac{1}{2}$6J6	B	Delay Multivibrator
V_{11}	6C4	B	Slave Blocking Oscillator
V_{13} (X_{12})	$\frac{1}{2}$5670	A	Free Running Blocking Oscillator
V_{14}	$\frac{1}{2}$6J6	D	Delay Multivibrator
V_{15} (X_{14})	$\frac{1}{2}$6J6	D	Delay Multivibrator
V_{16}	6C4	D	Slave Blocking Oscillator
V_{17}	$\frac{1}{2}$5670	D	Cathode Follower
V_{18}	$\frac{1}{2}$6J6	E	Delay Multivibrator
V_{19} (X_{18})	$\frac{1}{2}$6J6	E	Delay Multivibrator
V_{20}	6C4	E	Slave Blocking Oscillator
V_{21} (X_{17})	$\frac{1}{2}$5670	E	Cathode Follower
V_{22}	$\frac{1}{2}$6J6	F	Delay Multivibrator
V_{23} (X_{22})	$\frac{1}{2}$6J6	F	Delay Multivibrator
V_{24}	6C4	F	Slave Blocking Oscillator
V_{25}	$\frac{1}{2}$5670	F	Cathode Follower

Tube	Type	Channel	Function
V_{26}	½6J6	G	Delay Multivibrator
V_{27} (X_{26})	½6J6	G	Delay Multivibrator
V_{28}	6C4	G	Slave Blocking Oscillator
V_{29} (X_{25})	½5670	G	Cathode Follower
V_{30}	½6J6	H	Delay Multivibrator
V_{31} (X_{30})	½6J6	H	Delay Multivibrator
V_{32}	6C4	H	Slave Blocking Oscillator
V_{33}	½5670	H	Cathode Follower
V_{34}	OA2	J	Voltage Regulator
V_{35}	6X4	J	Full Wave Rectifier
V_{36}	6X4	J	Full Wave Rectifier
V_{37}	6X4	J	Full Wave Rectifier
V_{38}	6AS7G	J	Current Control
V_{39}	6AK5	J	Bias Control
V_{40}	½5670	G	Cathode Follower
V_{41}	6AN5	K	Inverter-Amplifier
V_{43}	½5670	D	Cathode Follower
V_{44} (X_5)	½5670	E	Cathode Follower
V_{45} (X_{43})	½5670	F	Cathode Follower
V_{46} (X_{40})	½5670	H	Cathode Follower
V_{47}	6AN5	K	Inverter-Amplifier
V_{48}	½5670	K	Cathode Follower
V_{49} (X_{48})	½5670	K	Cathode Follower

All resistors ½ watt unless otherwise noted.

R	Channel	Size	R	Channel	Size
2	C	500K 2W pot.	33	B	15K
3	C	100K 2W pot.	34	B	220 ohm
4	C	1K 2W pot.	35	B	10K 1W
5	A	5M 2W pot.	36	B	220K
7	D	500K 2W pot.	37	B	270K
8	J	100K 2W pot.	38	C	9.1K
9	E	500K 2W pot.	39	C	56K
10	F	500K 2W pot.	40	C	470K
11	G	500K 2W pot.	41	C	10K 1W
12	H	500K 2W pot.	42	C	560K
13	J	82K 1W	43	C	10K 1W
14	J	68K	44	C	47K
15	J	300K	45	C	6.8K
18	J	11.2K 5W	46	C	13.2K 1W
20	J	500 ohm 20W (tapped)	47	C	100 ohm
24	A	2.7K	48	C	5.1K
25	A	100 ohm	50	C	91 ohm
26	A	5.1K	51	C	13.8K 1W
27	B	10K 1W	52	C	100K
28	B	470K	53	C	6.8K
29	B	50K	54	C	100K
30	B	500K2wpot.	55	C	910 ohm
31	B	560K	56	C	5.6K 1W
32	B	10K 1W	57	C	82K 1W

R	Channel	Size	R	Channel	Size
58	K	270K	83	D	10K 1W
59	K	680K	84	D	100 ohm
60	K	1.5K 1W	85	D	220K
61	K	68K	86	D	270K
62	K	220K	87	D	820K
63	K	3.3M	88	D	6.8K
64	K	1M	89	E	820K
65	K	3.3M	90	E	6.8K
66	K	8.9K 2W	91	E	56K
67	K	41K	92	E	470K
68	K	4K	93	E	10K 1W
69	K	2.5K 1W	94	E	560K
70	K	68K	95	E	10K 1W
71	K	56K	96	E	15K
72	K	47K	97	E	10K 1W
73	K	3.3K	98	E	100 ohm
74	K	100K	99	E	220K
75	D	820K	100	E	270K
76	D	6.8K	101	E	820K
77	D	56K	102	E	6.8K
78	D	470K	103	F	820K
79	D	10K 1W	104	F	6.8K
80	D	560K	105	F	56K
81	D	10K 1W	106	F	470K
82	D	15K	107	F	10K 1W

R	Channel	Size
108	F	560K
109	F	10K 1W
110	F	15K
111	F	10K 1W
112	F	100 ohm
113	F	220K
114	F	270K
115	F	820K
116	F	6.8K
117	G	820K
118	G	6.8K
119	G	56K
120	G	470K
121	G	10K 1W
122	G	560K
123	G	10K 1W
124	G	15K
125	G	10K 1W
126	G	100 ohm
127	G	220K
128	G	270K
129	G	820K
130	G	6.8K
131	H	820K

R	Channel	Size
132	H	6.8K
133	H	56K
134	H	470K
135	H	10K 1W
136	H	560K
137	H	10K 1W
138	H	15K
139	H	10K 1W
140	H	100 ohm
141	H	220K
142	H	270K
143	H	820K
144	H	6.8K
145	H	2.2K
146	C	10K

All capacitors 200 WV unless otherwise noted.

C	Channel	Size	C	Channel	Size
1	J	40 mf 450 WV	27	C	.05
2	J	40 mf 450 WV	28	C	.05
5	A	100	29	C	400 300 WV
6	B	.05 300 WV	30	C	.25
7	B	100 300 WV	32	K	.001
8	B	100	33	K	.1 300 WV
9	B	32	34	K	.01 300 WV
10	B	62	35	K	.01
11	B	.002	36	K	.001 300 WV
12	B	.01 300 WV	37	K	.01 300 WV
13	B	.01	38	K	.01
14	B	.05	39	K	.01
15	C	100	40	K	400 300 WV
16	C	100 300 WV	41	K	.01 300 WV
17	C	5	42	K	.01
18	C	.002	43	K	.05
19	C	.1 300 WV	44	K	.01 300 WV
20	C	.01	45	D	100 300 WV
21	C	.005	46	D	100
22	C	100 300 WV	47	D	10 300 WV
23	C	200	48	D	62
24	C	.001 300 WV	49	D	.002
25	C	.068	50	D	.01 300 WV
26	C	.01	51	D	.01

C	Channel	Size
52	D	.05
53	E	100 300 WV
54	E	100
55	E	10 300 WV
56	E	62
57	E	.002
58	E	.01 300 WV
59	E	.01
60	E	.05
61	F	100 300 WV
62	F	100
63	F	10 300 WV
64	F	62
65	F	.002
66	F	.01 300 WV
67	F	.01
68	F	.05
69	G	100 300 WV
70	G	100
71	G	10 300 WV
72	G	62
73	G	.002
74	G	.01 300 WV
75	G	.01
76	G	.05
77	H	100 300 WV
78	H	100
79	H	10 300 WV
80	H	62
81	H	.002
82	H	.01 300 WV
83	H	.01
84	H	.05

CROSS INDEX CHANNELS (D)-(H)

Channel (D)	Channel (E)	Channel (F)	Channel (G)	Channel (H)
V_{43}	V_{44} (X-5)	V_{45} (X-43)	V_{40}	V_{46} (X-40)
V_{14}	V_{18}	V_{22}	V_{26}	V_{30}
V_{15} (X-14)	V_{19} (X-18)	V_{23} (X-22)	V_{27} (X-26)	V_{31} (X-30)
V_{16}	V_{20}	V_{24}	V_{28}	V_{32}
V_{17}	V_{21} (X-17)	V_{25}	V_{29} (X-25)	V_{33}
R_{75}	R_{89}	R_{103}	R_{117}	R_{131}
R_{76}	R_{90}	R_{104}	R_{118}	R_{132}
R_{77}	R_{91}	R_{105}	R_{119}	R_{133}
R_{78}	R_{92}	R_{106}	R_{120}	R_{134}
R_{80}	R_{94}	R_{108}	R_{122}	R_{136}
R_{7}	R_{9}	R_{10}	R_{11}	R_{12}
R_{81}	R_{95}	R_{109}	R_{123}	R_{137}
R_{82}	R_{96}	R_{110}	R_{124}	R_{138}
R_{83}	R_{97}	R_{111}	R_{125}	R_{139}
R_{84}	R_{98}	R_{112}	R_{126}	R_{140}
R_{85}	R_{99}	R_{113}	R_{127}	R_{141}
R_{86}	R_{100}	R_{114}	R_{128}	R_{142}
R_{87}	R_{101}	R_{115}	R_{129}	R_{143}
R_{88}	R_{102}	R_{116}	R_{130}	R_{144}
R_{79}	R_{93}	R_{107}	R_{121}	R_{135}
C_{45}	C_{53}	C_{61}	C_{69}	C_{77}
C_{46}	C_{54}	C_{62}	C_{70}	C_{78}
C_{47}	C_{55}	C_{63}	C_{71}	C_{79}

Channel (D)	Channel (E)	Channel (F)	Channel (G)	Channel (H)
C_{48}	C_{56}	C_{64}	C_{72}	C_{80}
C_{49}	C_{57}	C_{65}	C_{73}	C_{81}
C_{50}	C_{58}	C_{66}	C_{74}	C_{82}
C_{51}	C_{59}	C_{67}	C_{75}	C_{83}
C_{52}	C_{60}	C_{68}	C_{76}	C_{84}
T_4	T_5	T_6	T_7	T_8
Y_7	Y_8	Y_9	Y_{10}	Y_{11}
Y_{12}	Y_{13}	Y_{14}	Y_{15}	Y_{16}
SW_3	SW_4	SW_5	SW_6	SW_7

* *

Cross reference TABLE for pulse generation channels (D) through (H).

WINDING DATA FOR [illegible] S

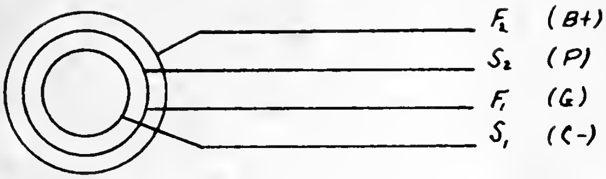
A universal pie type winding is required for trans-former. Start winding on aluminum former and bring out a tap at twelve turns (for feedback tap); continue winding, adding twelve more turns.

Wire size is #30SSE

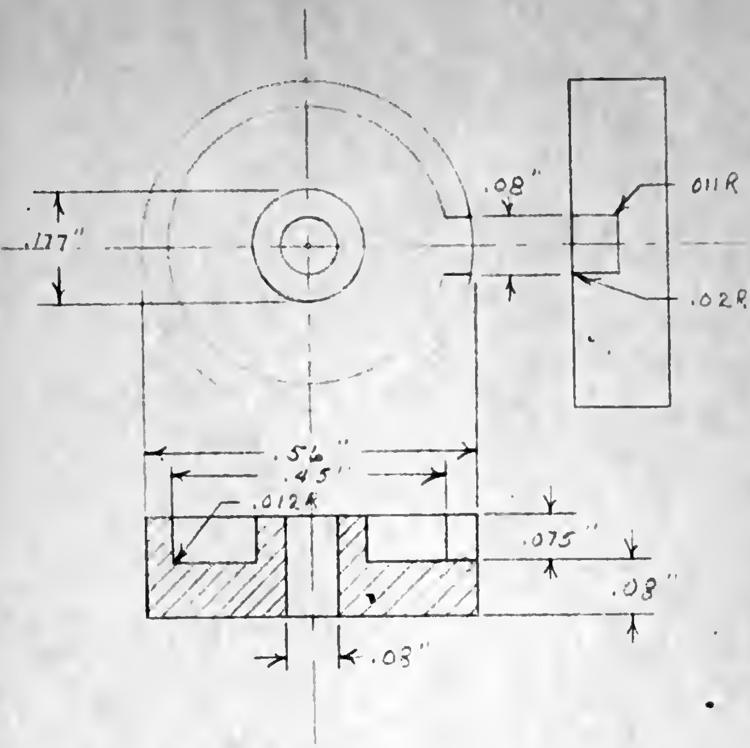
Mandrel is 3/16" O.D. Aluminum round stock...

Setup on Meissner Universal Machine:

Cam:	.187"
Cam gear:	#40
Drive gear:	#42



See Drawing DA3 and detailed analysis of Channel (A) for further assembly and mounting details.

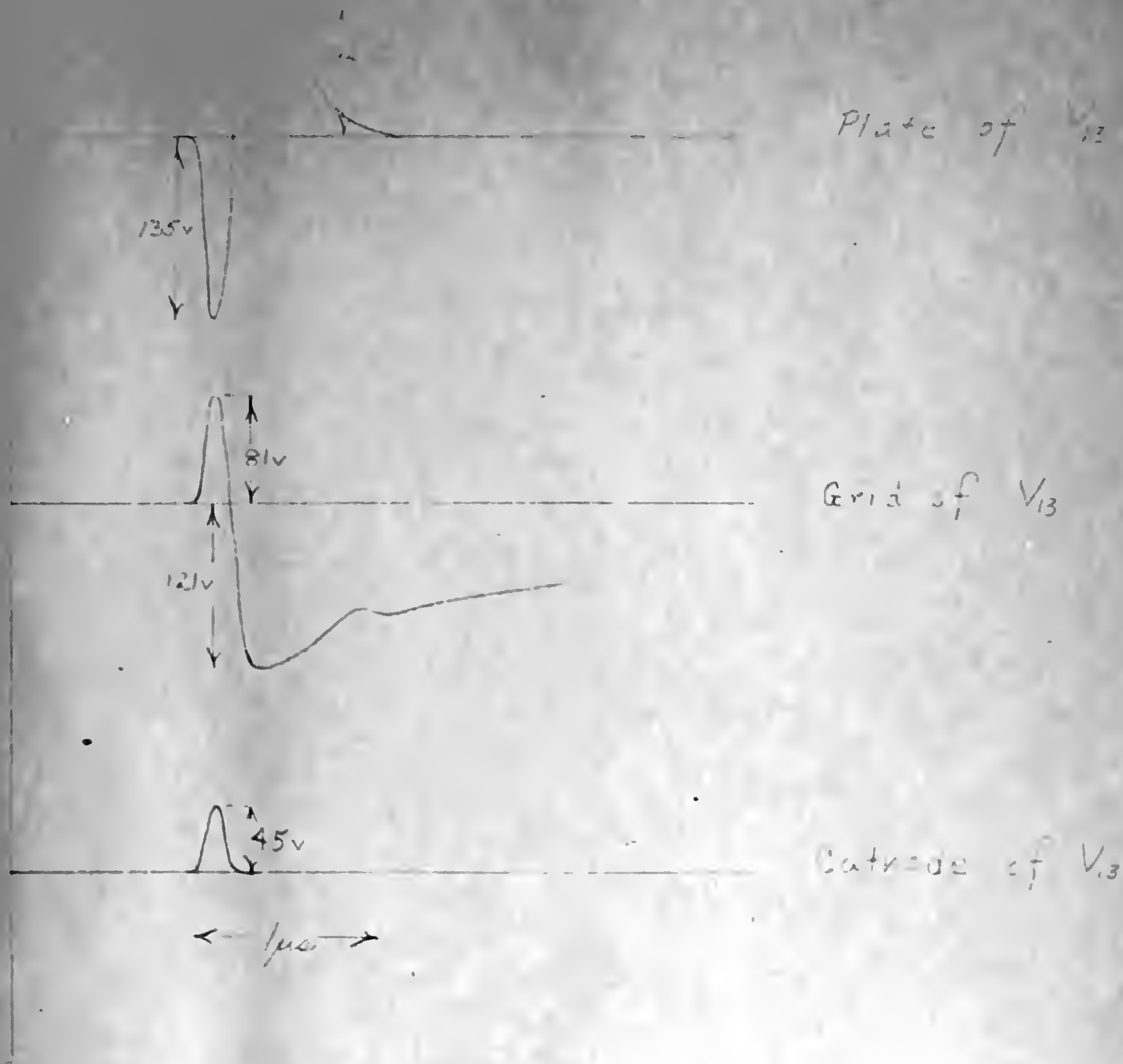


Dimensional Details of Pot Core Type 7F154, manufactures by the FERROXCUBE Corporation.

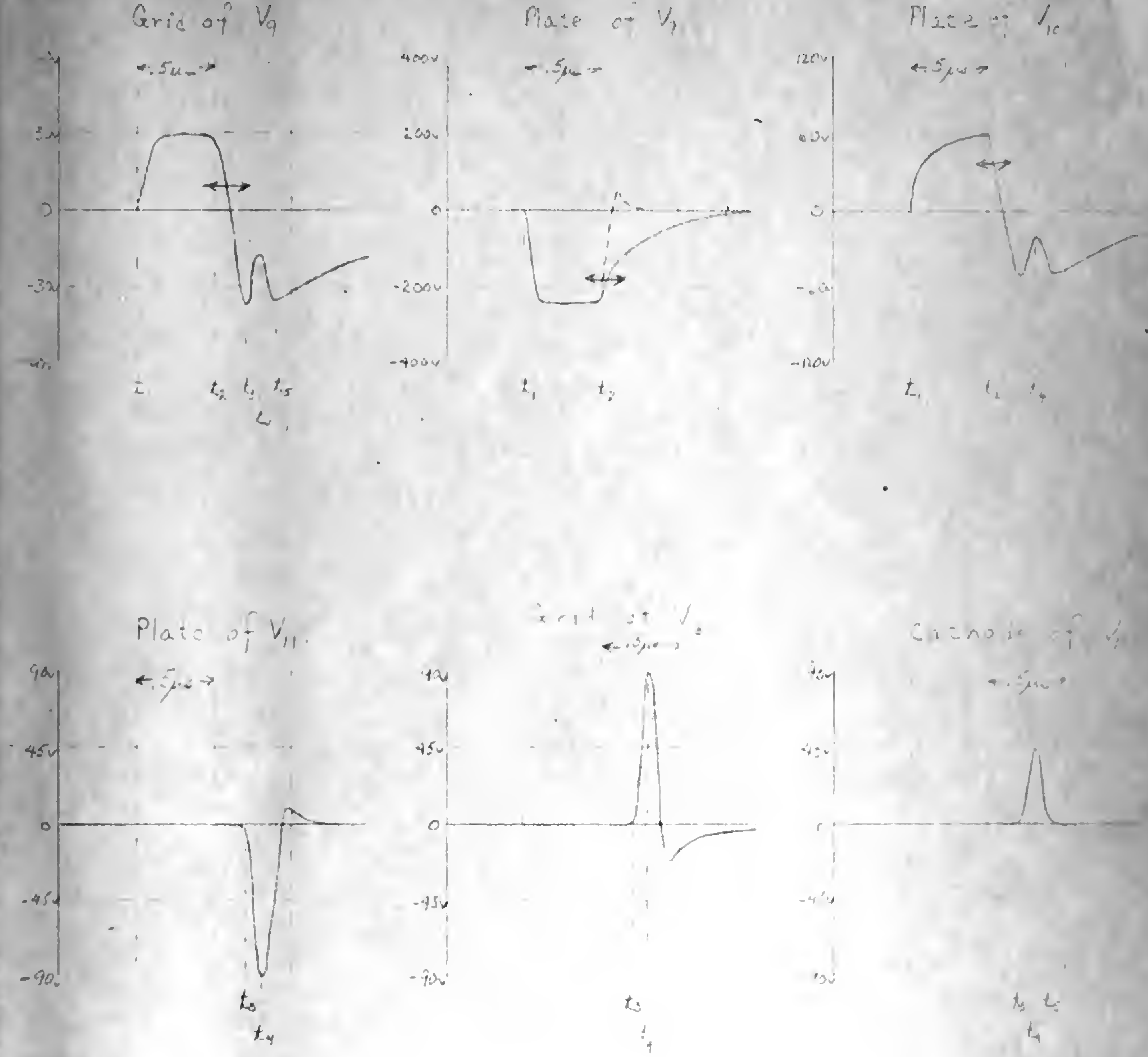
Connector Color Code

Pin	Xmtr Chassis	Power Chassis	Purpose
A	Grey	Clear	Filament
B			
C	Grey	Clear	Filament
D	Blue	Blue	100K pot (hi side)
E			
F	Blue	Blue	100K pot. (lo side)
G			
H	Brown	Black-Grey/White	Ground
I			
J			
K	White	Green-Black/White	-42 volts
L	Olive	Yellow-Black/White	115 volts a.c.
M	Olive	Red	H.V. Xfmr (hi)
N	Clear	Blue-Black/White	100K pot. (ctr. tap)
O			
P	Pink	Red-Black/White	260 volts
Q			
R	Brown	White	Fil. Xfmr (hi)

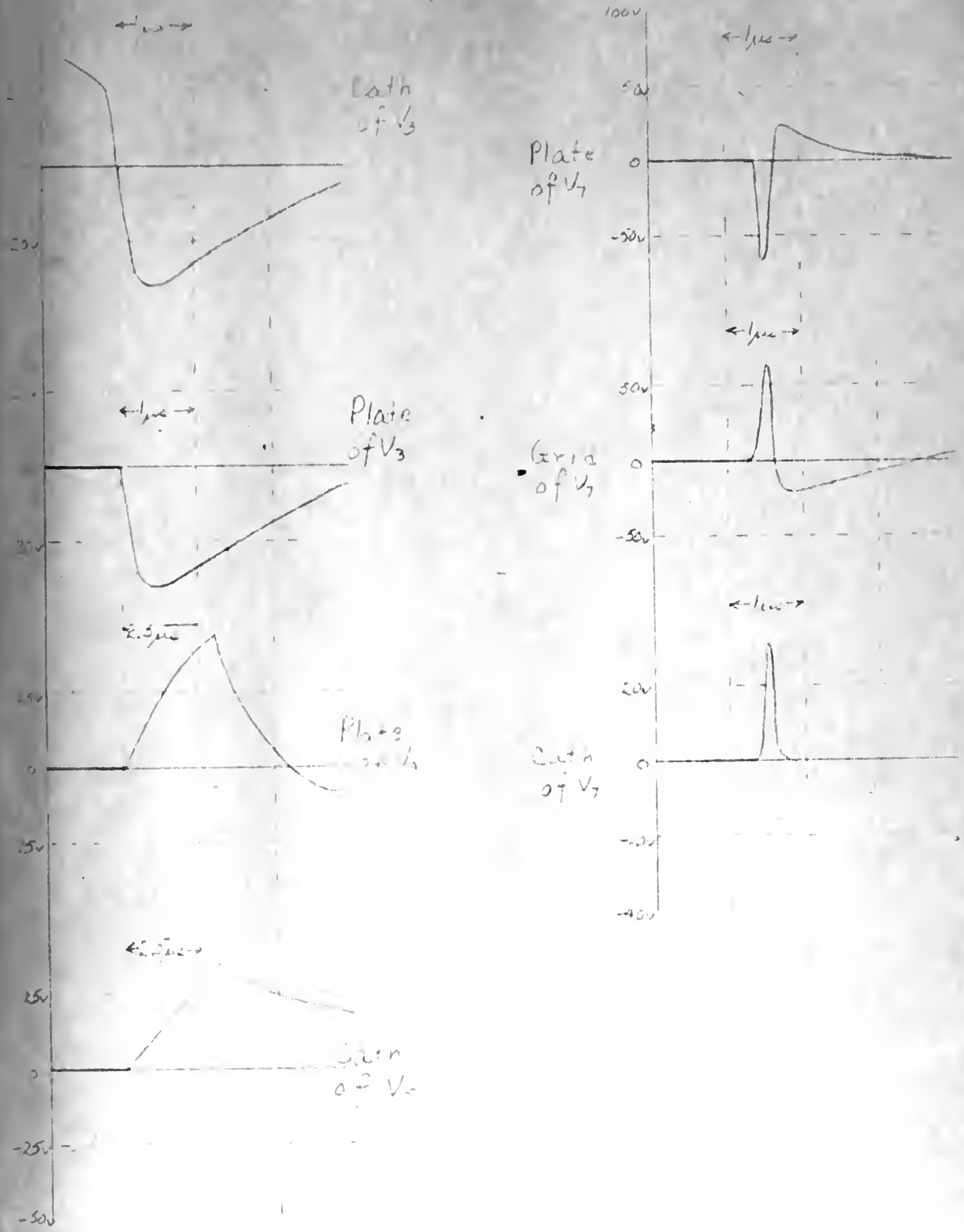
The hi. side of the H V and Fil Xfmrs. is the side which is fused and which comes to the Fil and H V switches on the front panel.



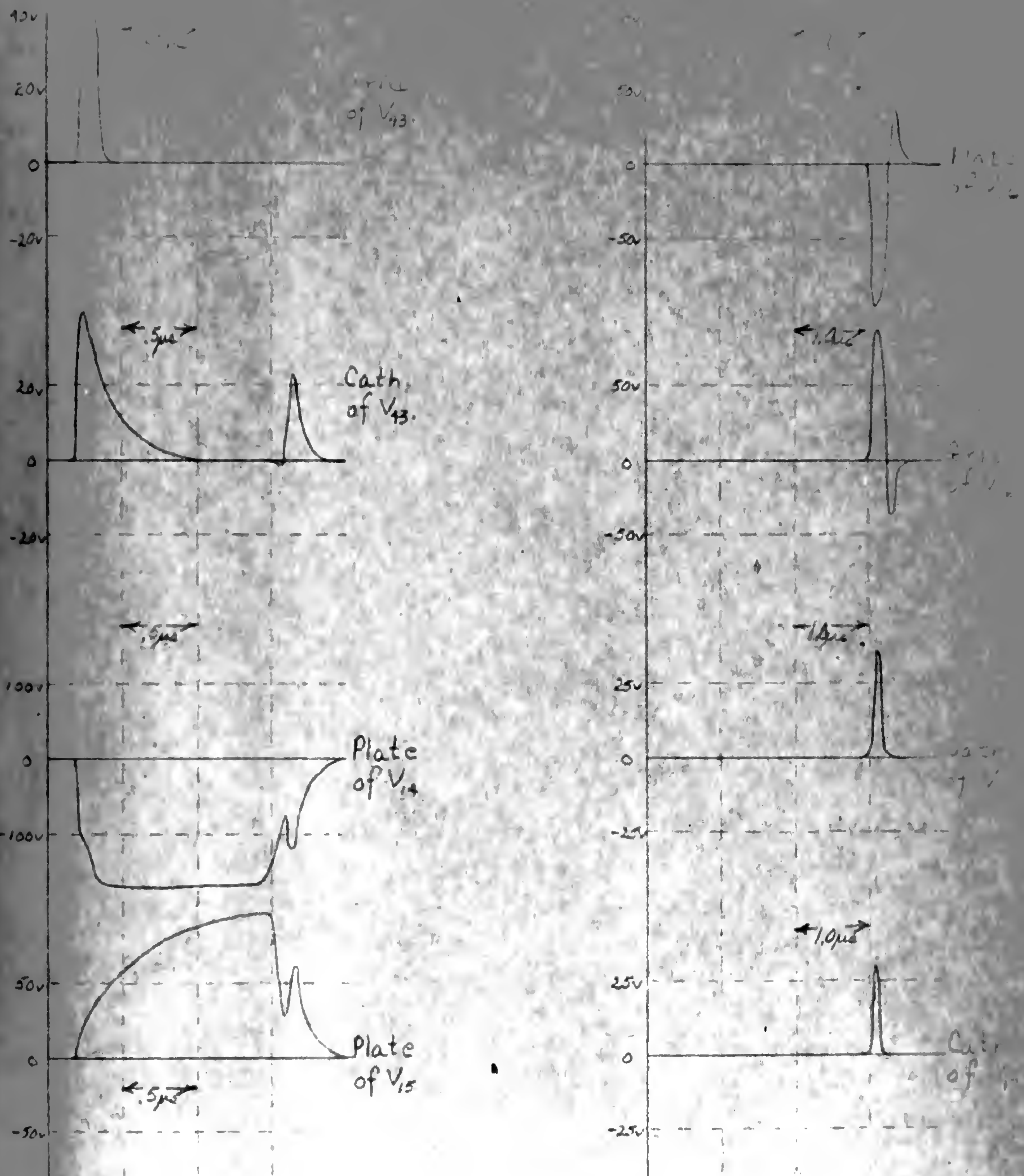
Waveforms for Channel [illegible]



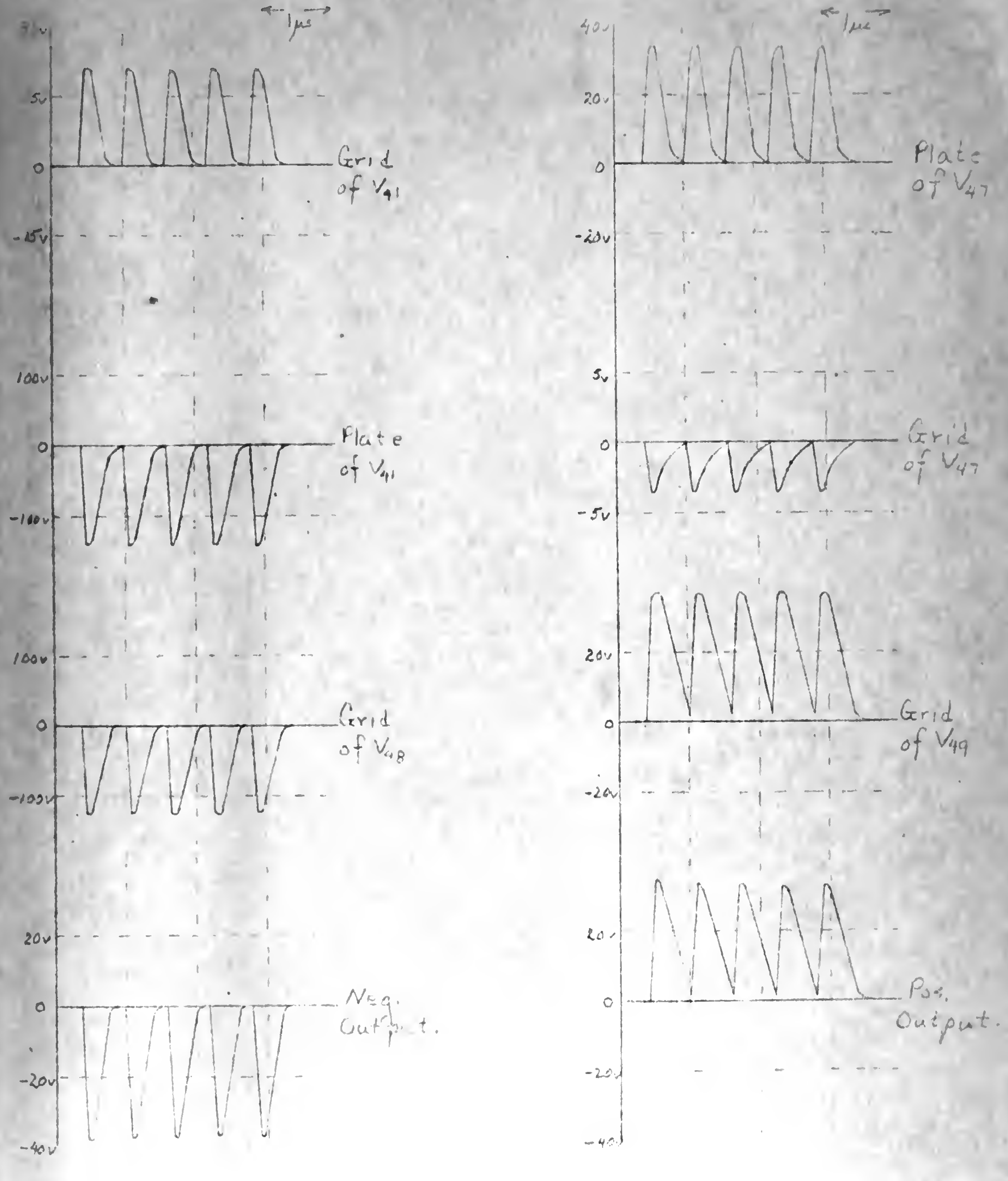
Waveforms for Channel (B)

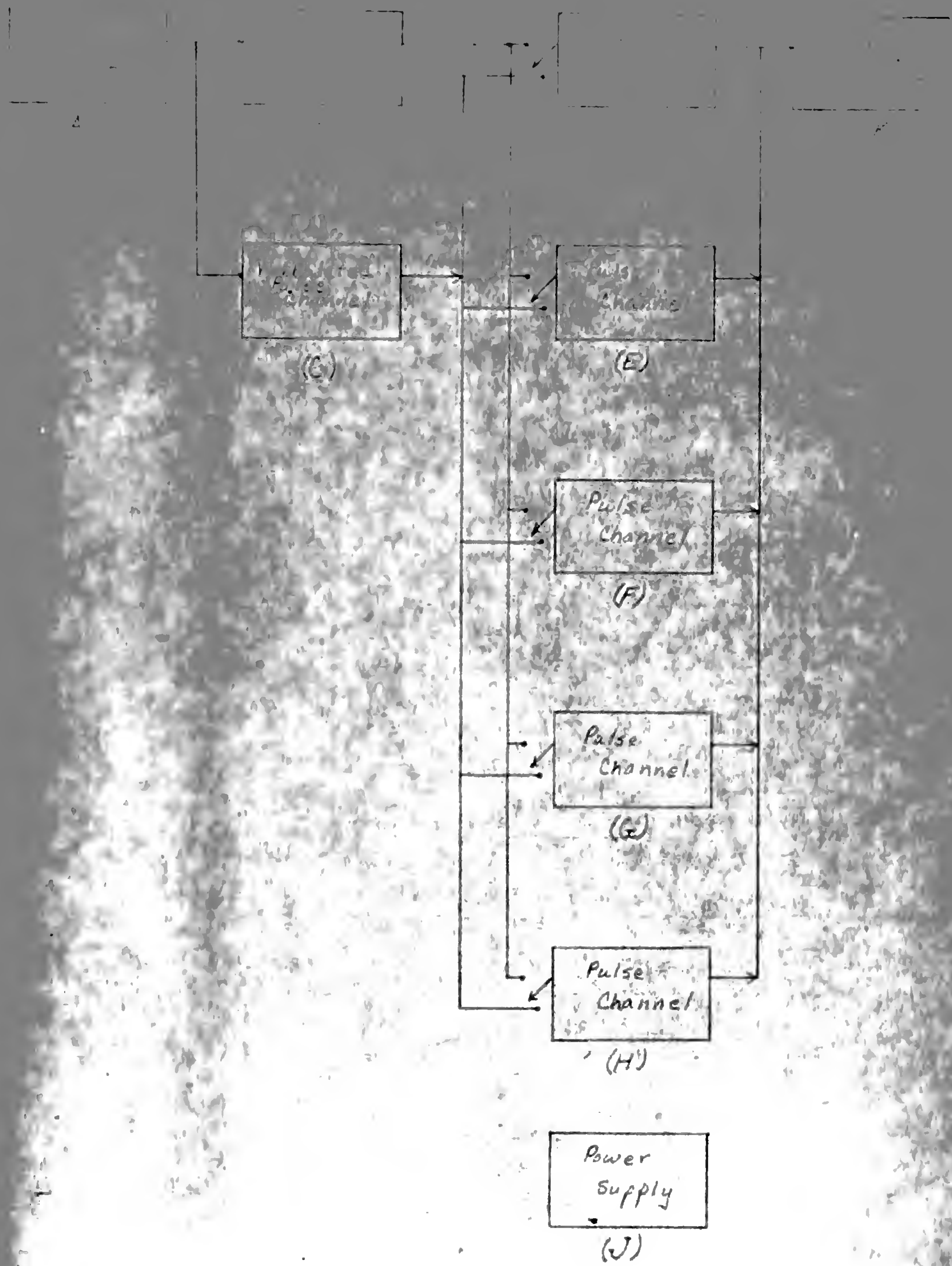


Wave... Channel (2)



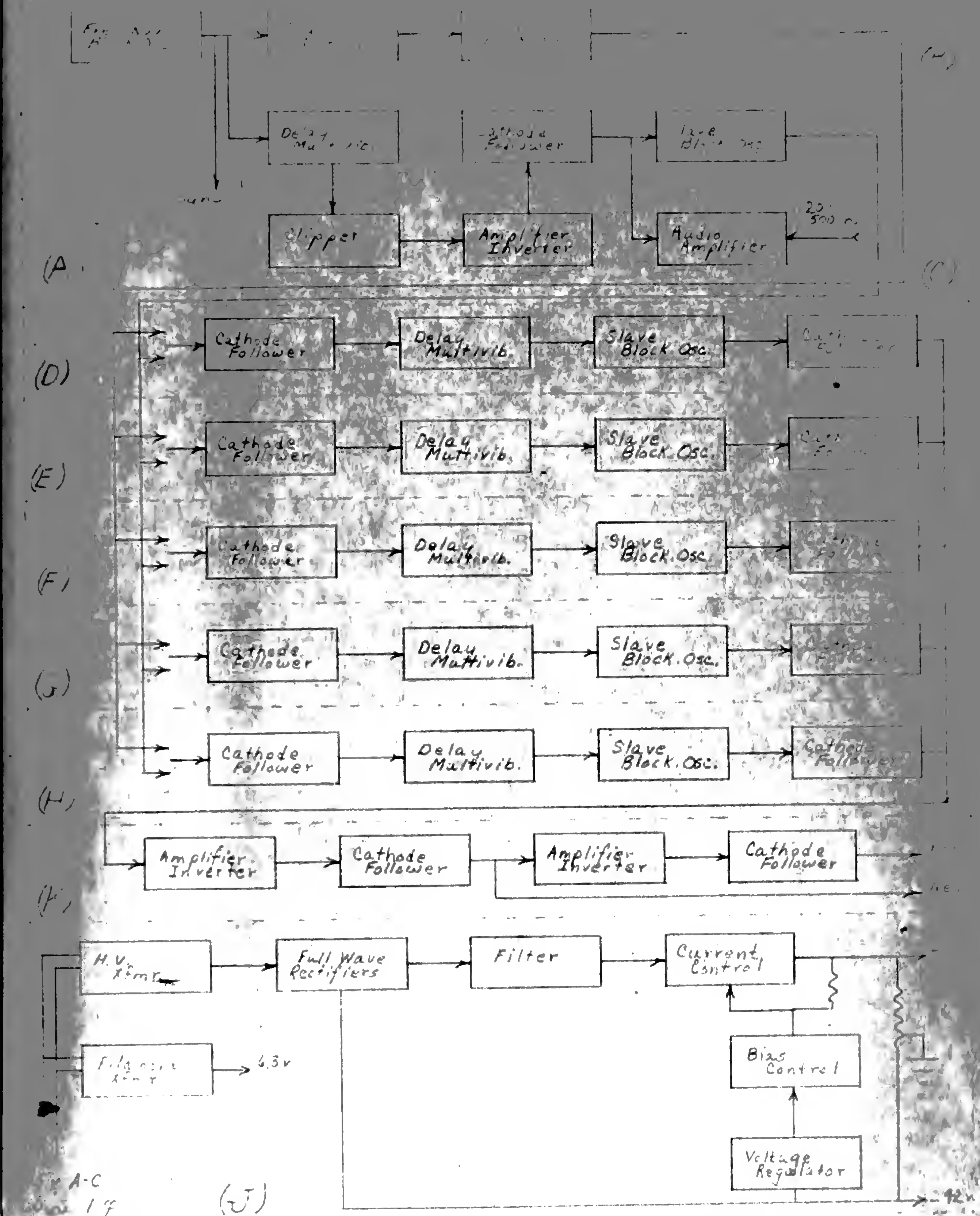
Waveforms for Channel (D) [through (H)].


1µs
5v
0
-15v
Grid of V41
100v
0
-100v
Plate of V41
100v
0
-100v
Grid of V48
20v
0
-20v
-40v
Neg. Output.
1µs
40v
20v
0
-20v
Plate of V47
5v
0
-5v
Grid of V47
20v
0
-20v
Grid of V49
20v
0
-20v
-40v
Pos. Output.

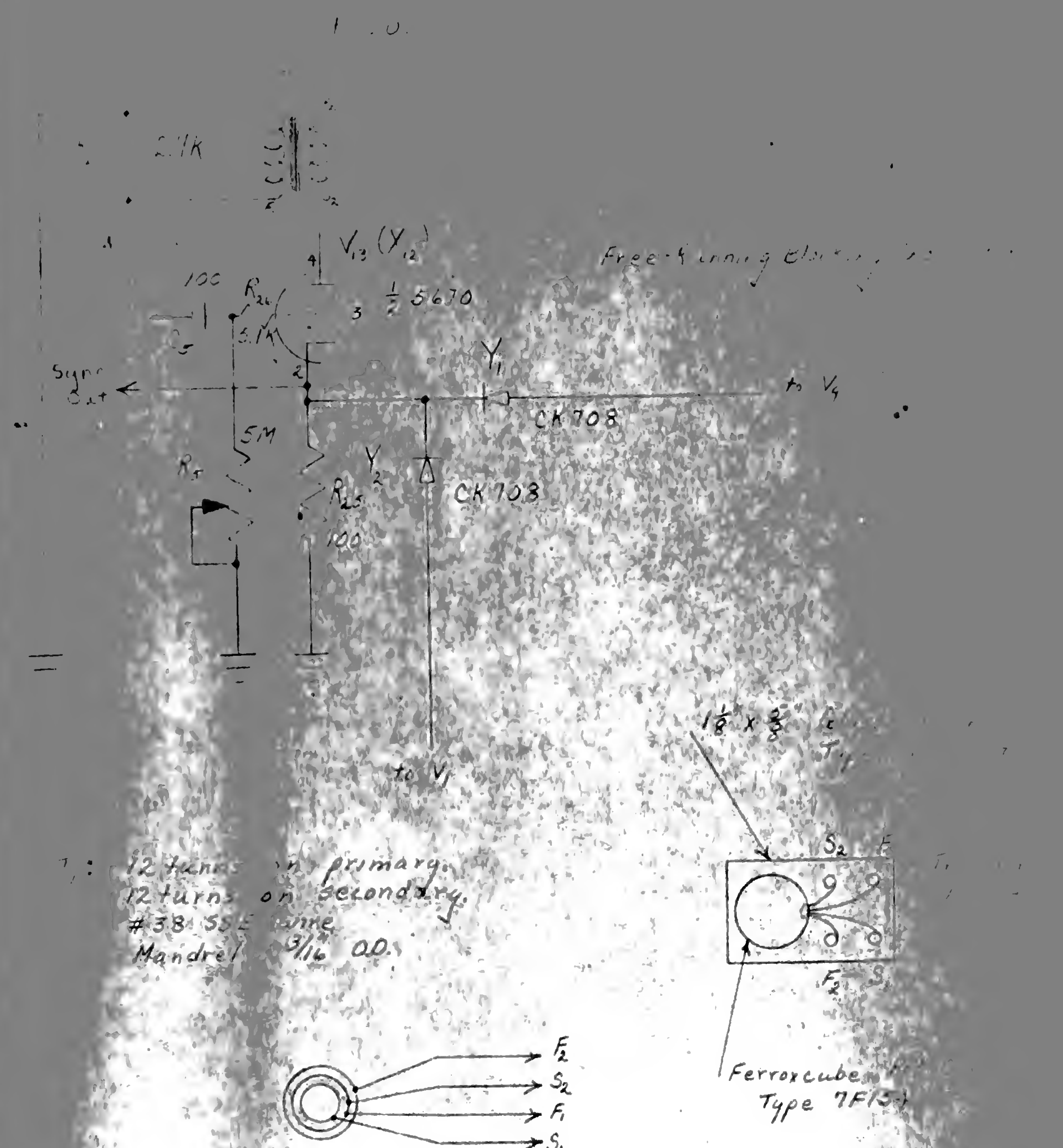


MAR 3 1952

SCALE	TITLE Simplified Block Diagram	MELPAR, INC. ALEXANDRIA, VA.	
DRAWN W. K. Pivesmith			
APPROVED	MATERIAL	PROJECT NO. 1153	EA 1
DATE 26 Feb 1952	FINISH		

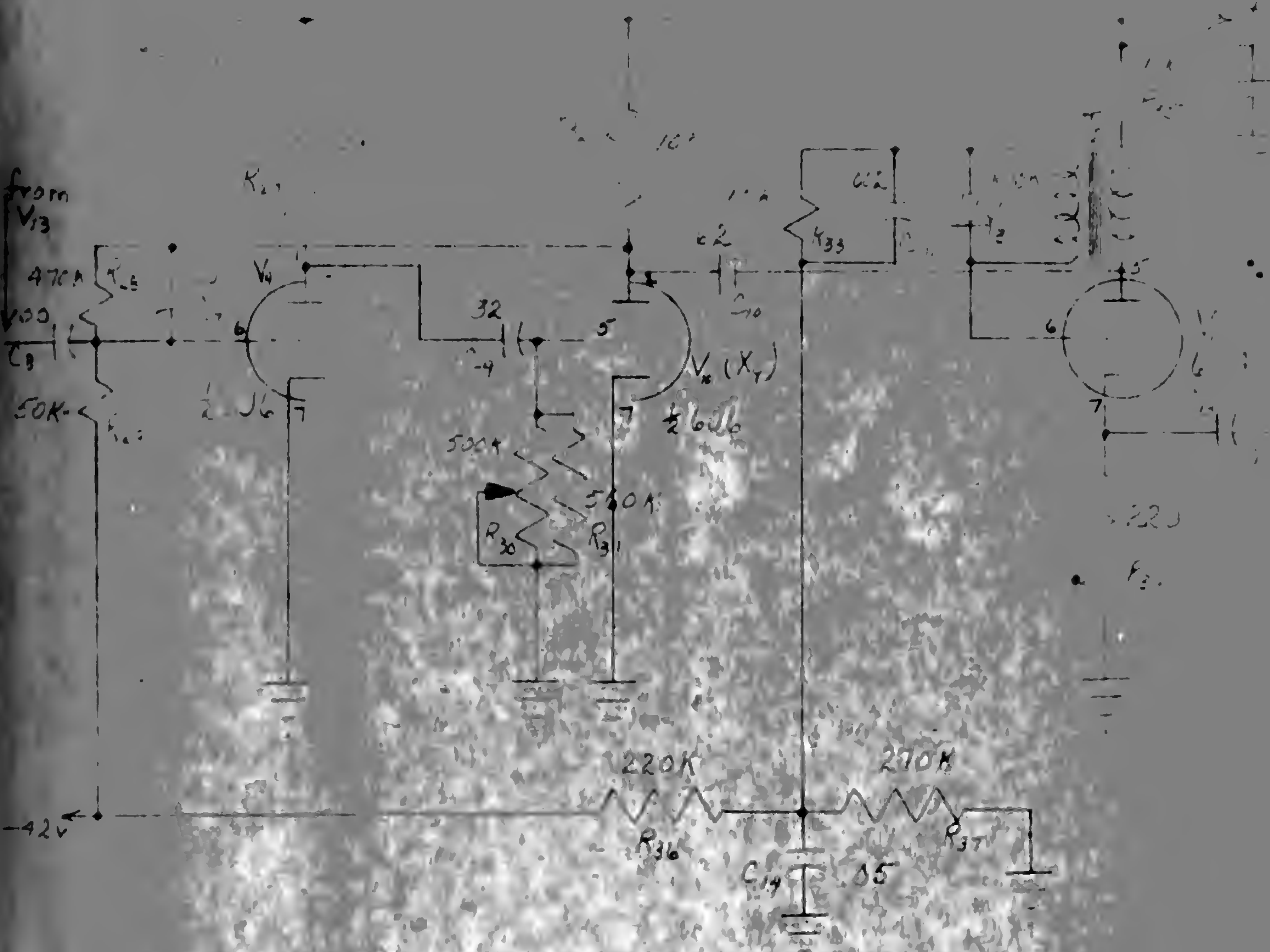


SCALE	TITLE Complete Block Diagram	MELPAR, INC. ALEXANDRIA, VA.
DRAWN		
APPROVED	MATERIAL	PROJECT NO # 1153 / EA 2 MAR 3 1952
DATE 1 Mar '52	FINISH	



MAR 7 1952

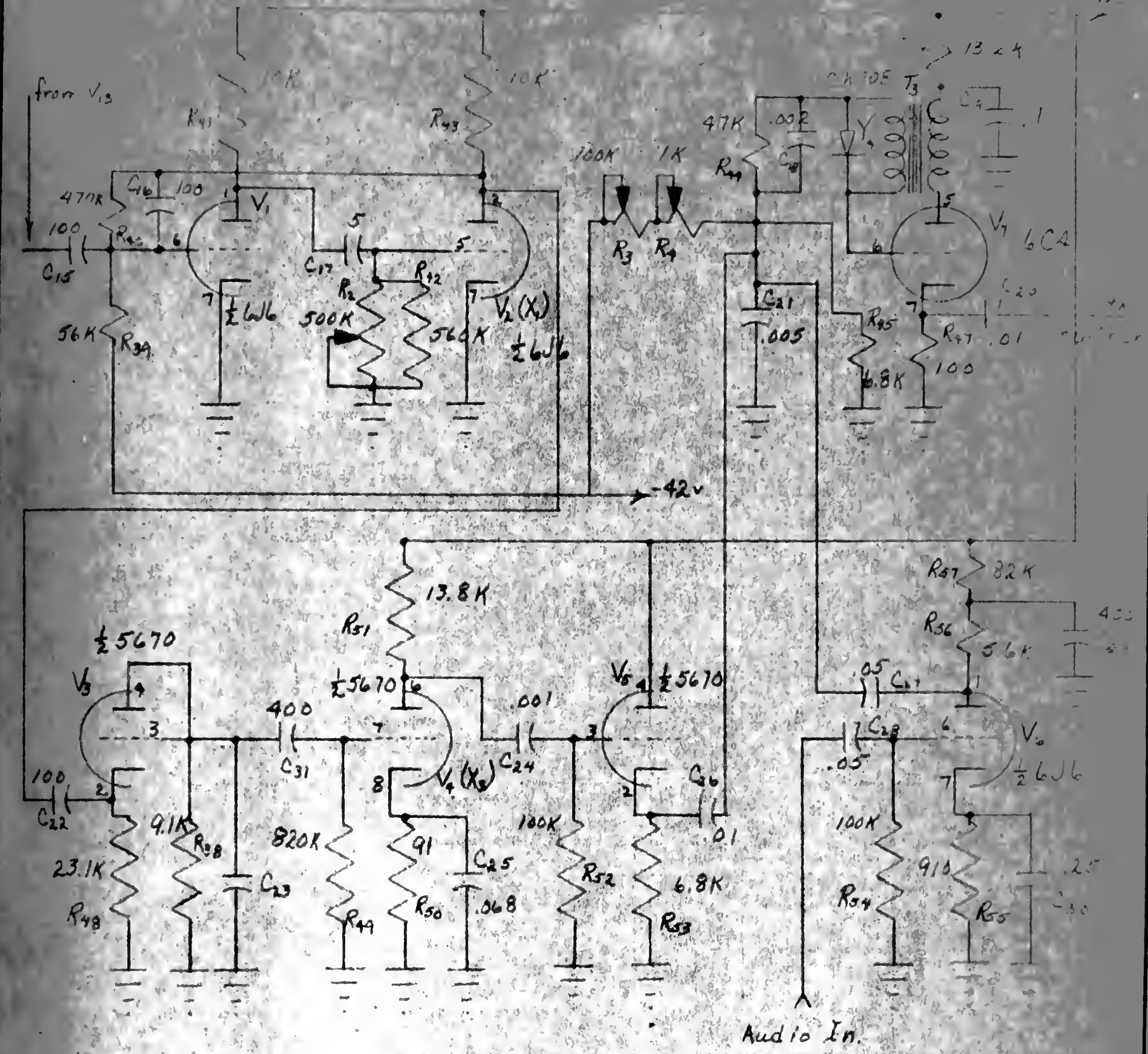
SCALE	TITLE Channel (A) of Modulator	MELPAR, INC. ALEXANDRIA, VA.	
DRAWN [signature]			
APPROVED	MATERIAL	PROJECT NO. # 1155	EA 3
DATE 3 March '52	FINISH		



T_2 ... data for T on dwg EA 3.

MAR 7 1952

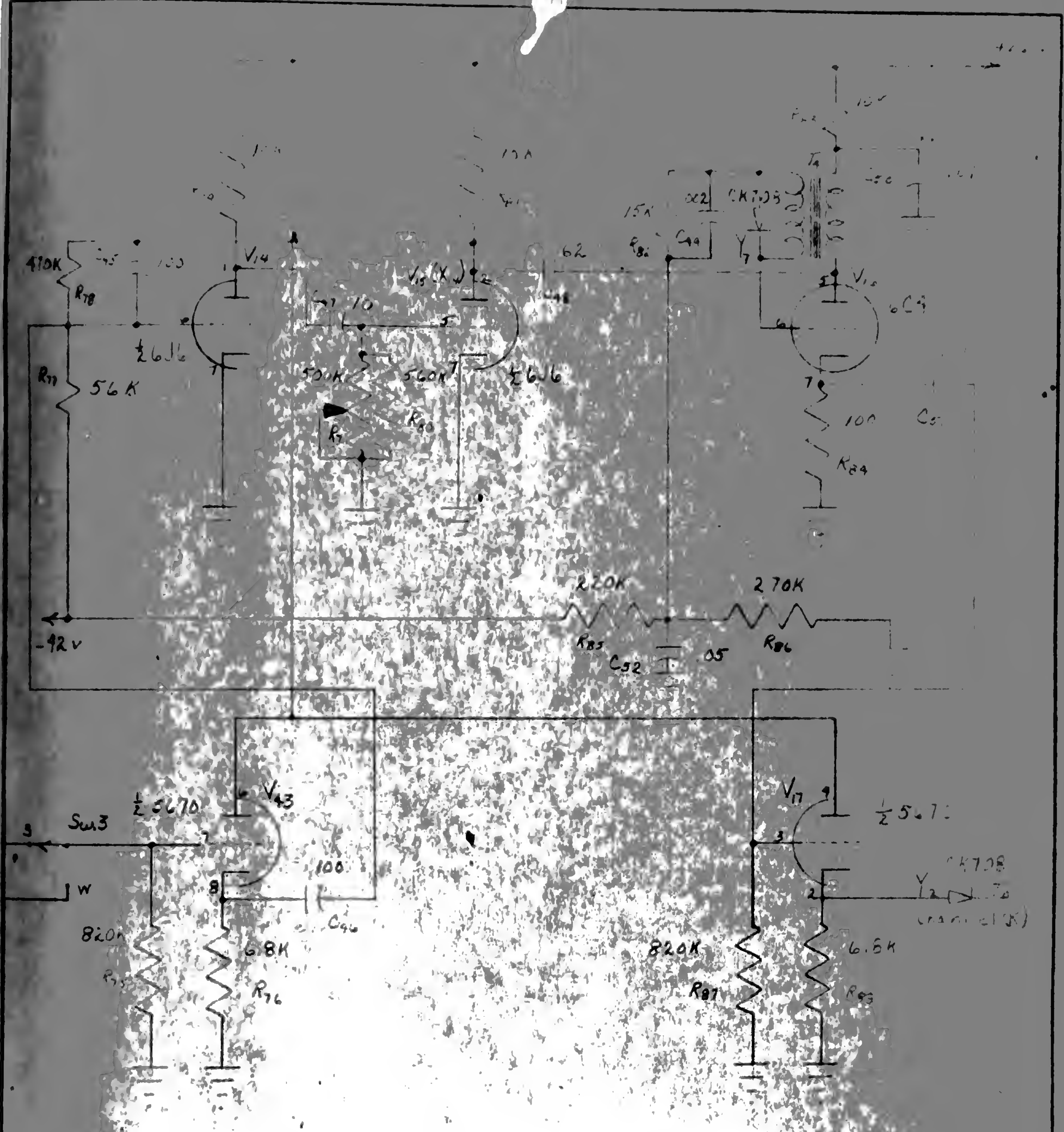
SCALE	TITLE	MELPAR, INC. ALEXANDRIA VA.	
DRAWN			
APPROVED	MATERIAL	PROJECT NO # 1153	EA 4
DATE Mar ... 52	FINISH		



C_{23} is the shunt and stray capacitance across R_{38} to gnd.

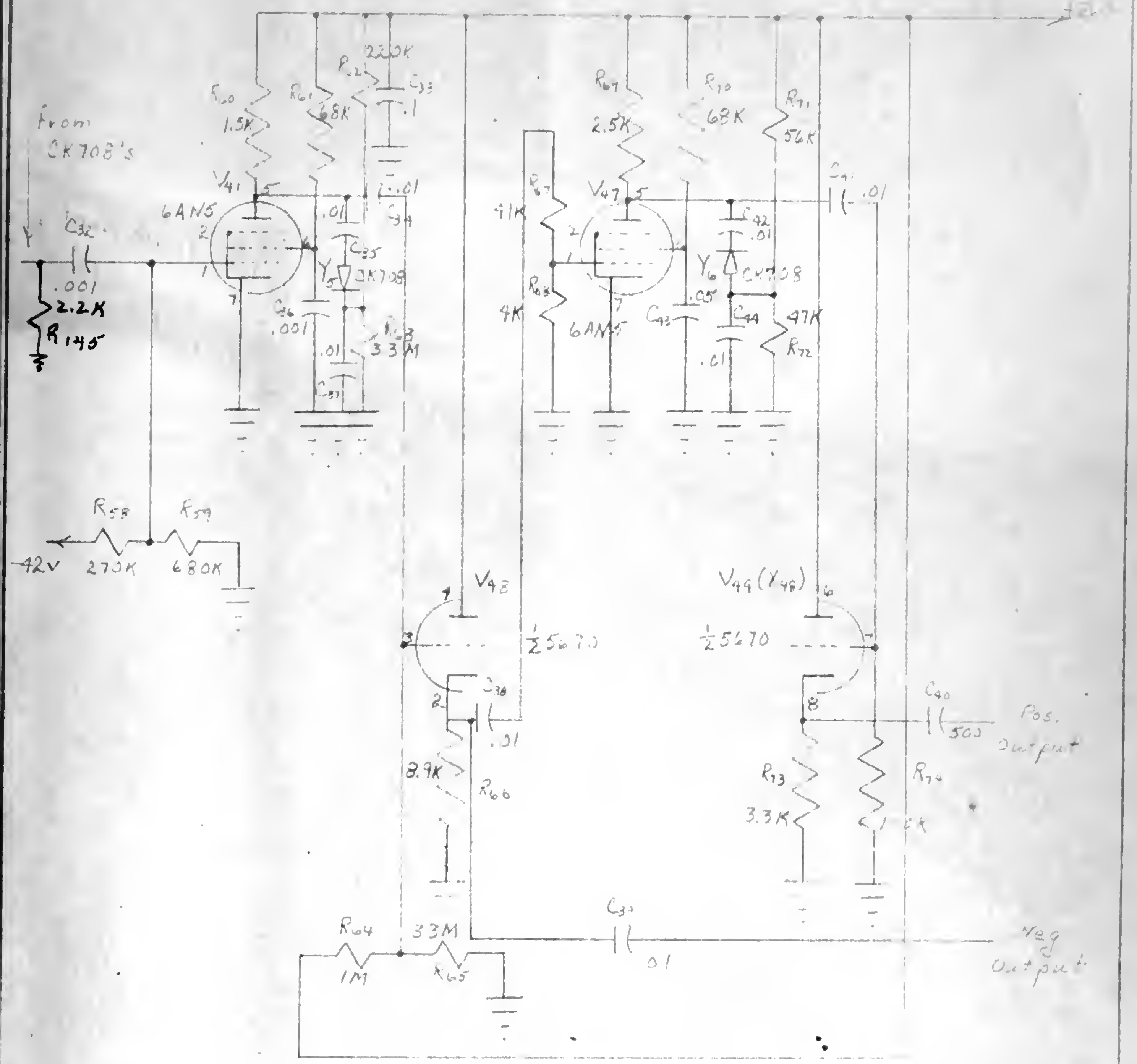
MAR 4 1952

SCALE	TITLE Channel (C) of Modulator	MELPAR, INC. ALEXANDRIA, VA.
DRAWN		
APPROVED	MATERIAL	PROJECT NO #1153 — EA 5
DATE 4 March 1952	FINISH	



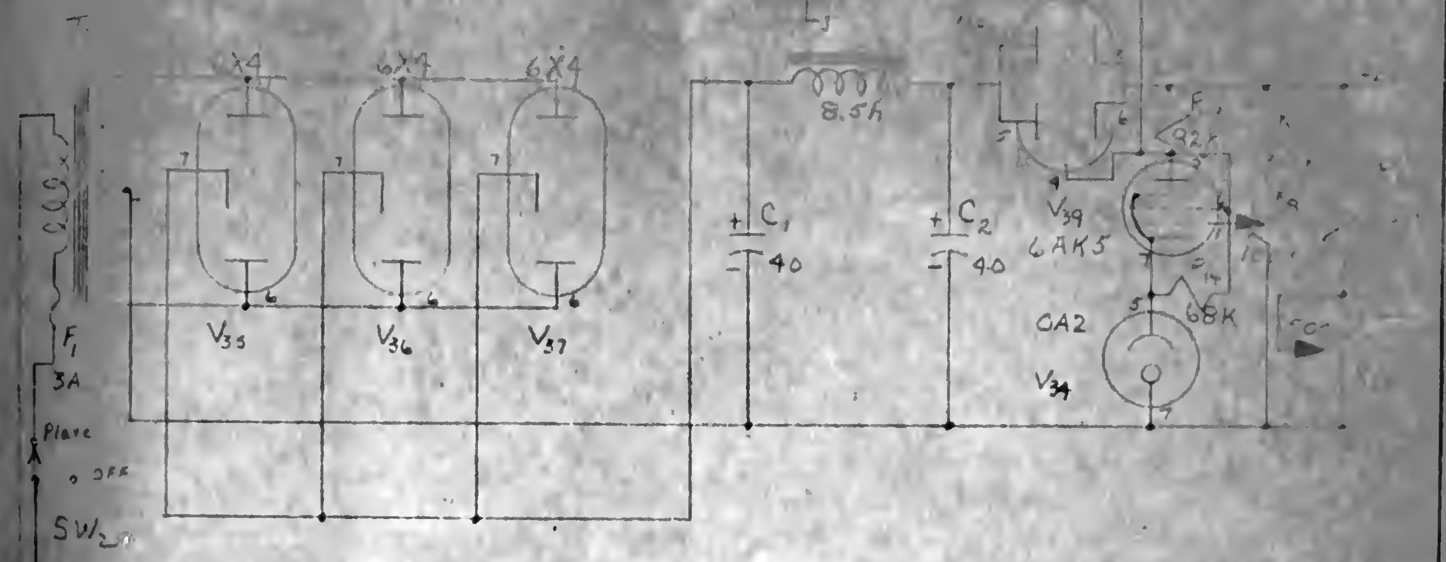
T_4: See data for T_1 on dwg. EA 3.

SCALE	TITLE Channel (D) of Modulator	MELPAR, INC. ALEXANDRIA, VA.	
DRAWN			
APPROVED	MATERIAL	PROJECT NO. #1153	EA 6
DATE March 1952	FINISH		

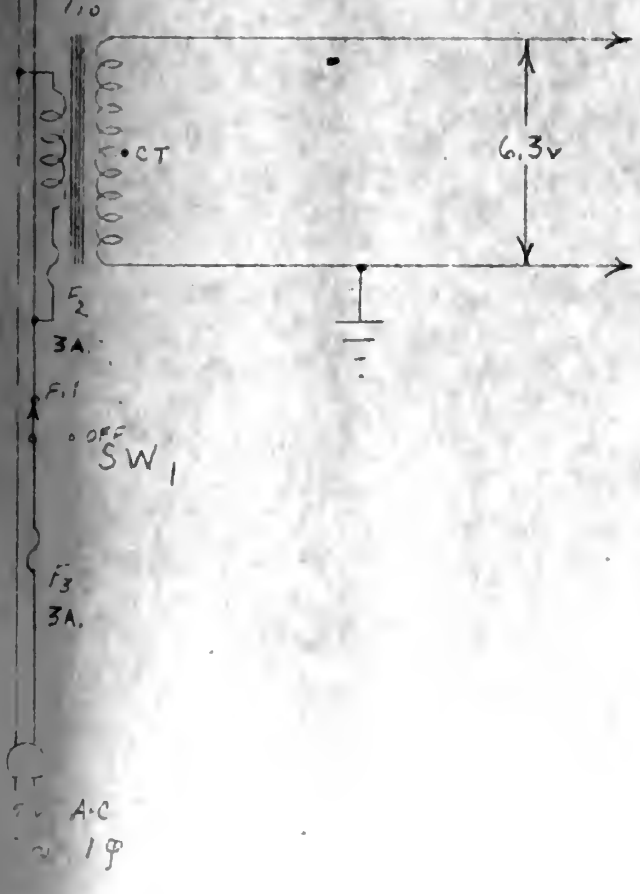


MAR 4 1952

SCALE	TITLE	MELPAR, INC.	
DRAWN		ALEXANDRIA VA	
APPROVED	MATERIAL	PROJECT NO	EA 7
DATE	FINISH		



R_{20} is a 20 watt, tapped, wire wound resistor

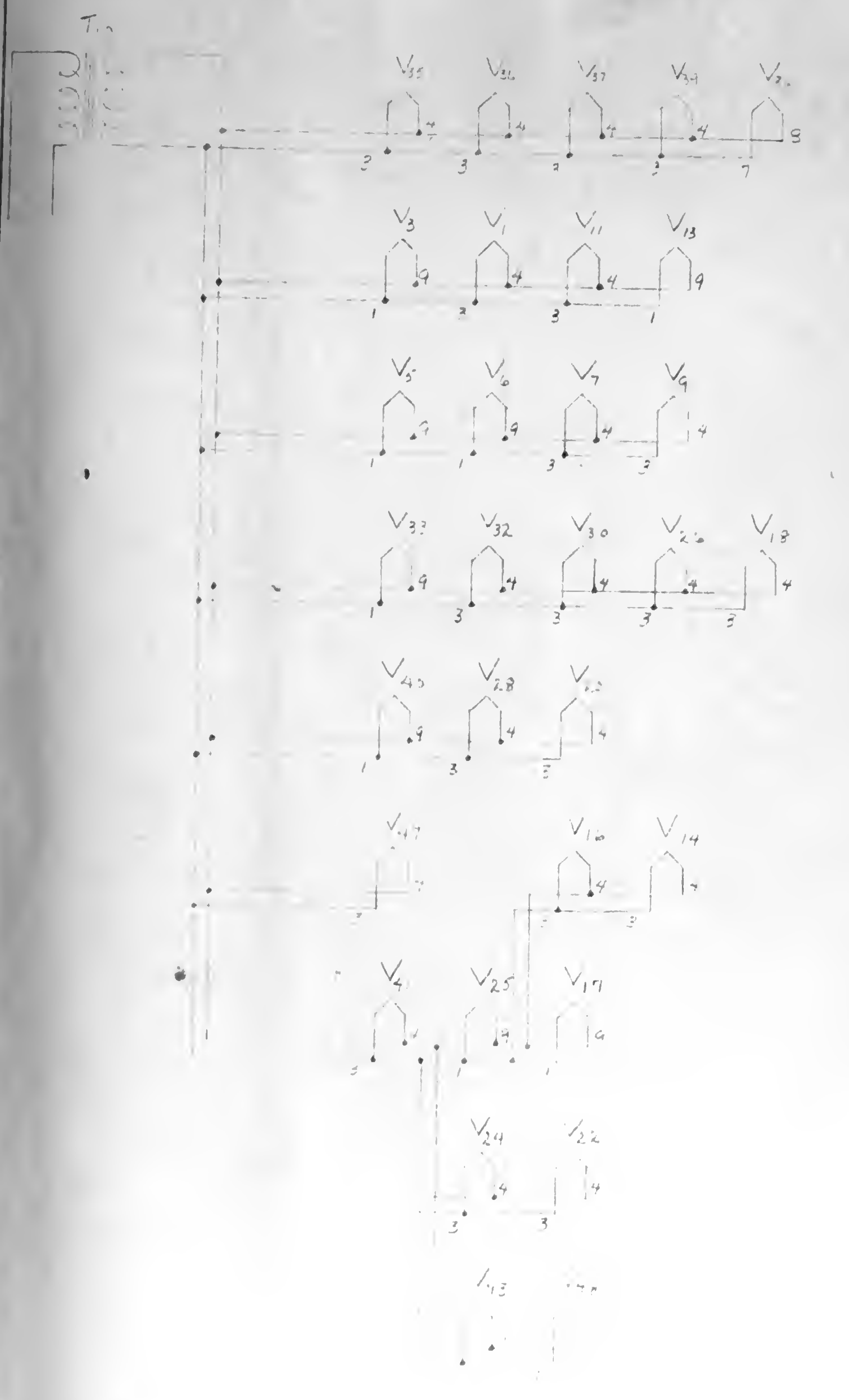


T_9 Stancor # P-6314 700v CT 200ma

T_{10} Stancor #.6308 6.3v CT 10 amp.

MAR 11 1952

SCALE	TITLE Power sup. (C) for Modulator	MELPAR, INC. ALEXANDRIA, VA.	
DRAWN			
APPROVED	MATERIAL	PROJECT NO #1153	EA 8
DATE 10 March 1952	FINISH		



MAR 11 1952

SCALE	TITLE	MELPAR, INC.
DRAWN		ALEXANDRIA VA
APPROVED	MATERIAL	
DATE	FINISH	EA 9

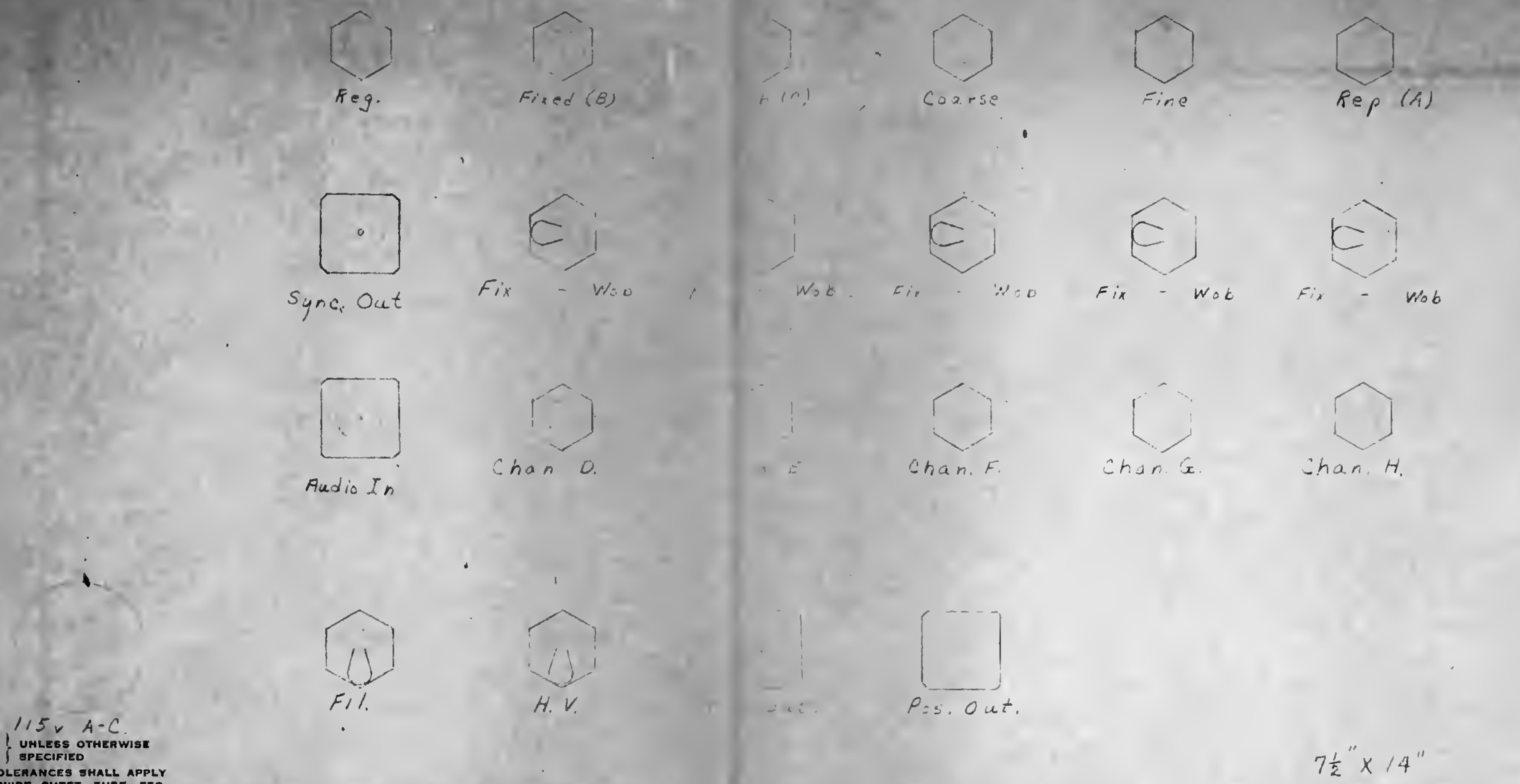
B

DECIMALS ±
FRACTIONS ±
COMMERCIAL PUBLISHED TOLERA
TO SIZES OF BAR, ROD, WIRE

UN
SPE

CHANGE:

"ALBANENE" NO. 1...M K&E CO., N.Y.



DECIMALS ±
FRACTIONS ±
} UNLESS OTHERWISE SPECIFIED

COMMERCIAL PUBLISHED TOLERANCES SHALL APPLY TO SIZES OF BAR, ROD, WIRE SHEET, TUBE, ETC.

CHANGE

REQ'D	DRAWING		ITEM	NAME	FIN.	ZONE	CIRCUIT SYMBOL
	USED ON	ASSY. DRWG.	QTY.				

MELPAR, INC. ELECTRONICS
ALEXANDRIA, VIRGINIA

Front Panel of Modulator
(actual size).

MAR 11 1954

DRAWN BY	ENGINEER	MATERIAL
[illegible signature]		
CHECKER	PROJ. ENGR.	FINISH
APPROVED	SCALE	B

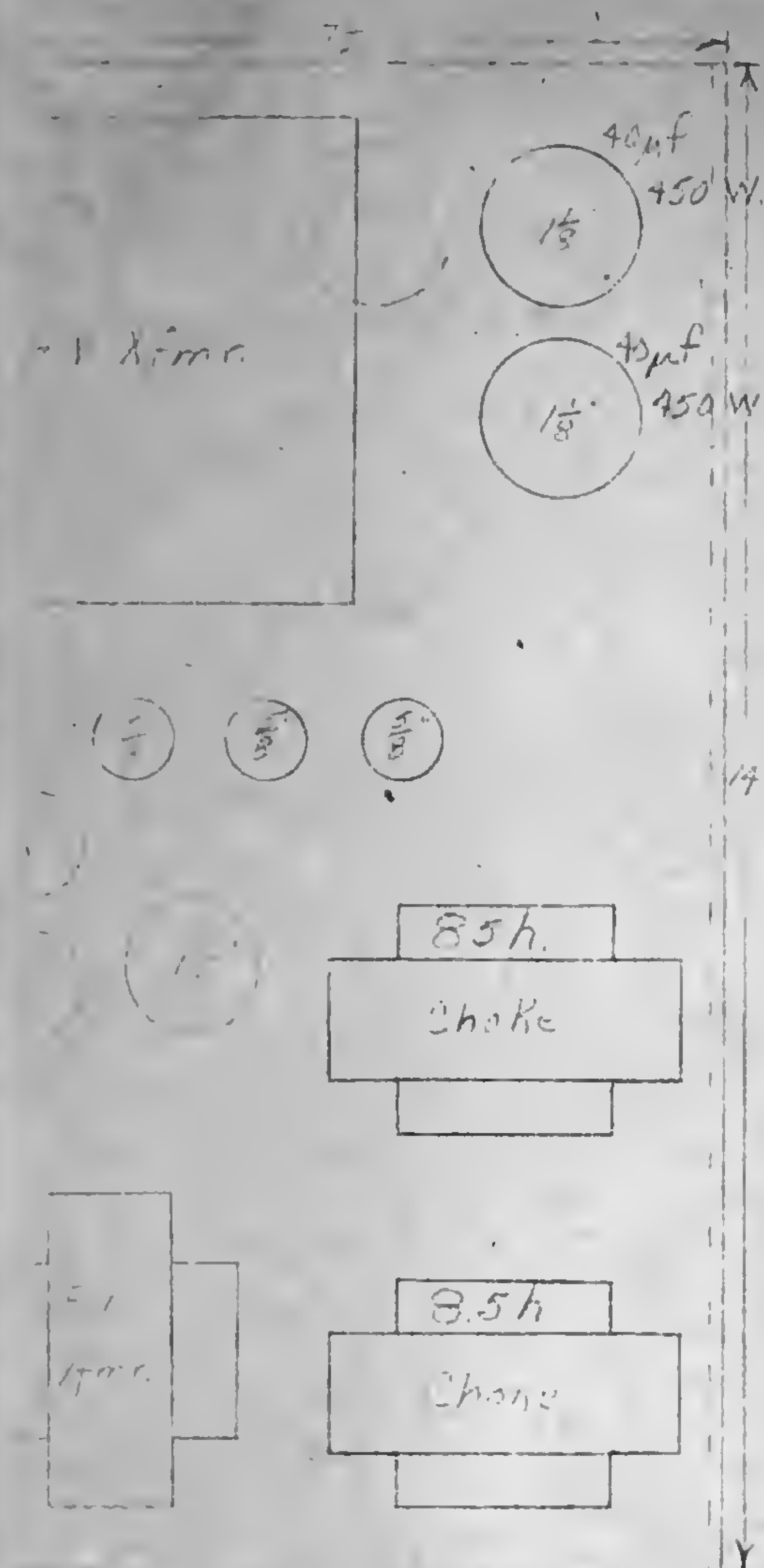
CHG.

B

B

DECIMALS ± } UNLESS OTHERWISE
FRACTIONS ± } SPECIFIED
COMMERCIAL PUBLISHED TOLERANCES SHALL APPLY TO SIZES OF BAR, ROD, WIRE SHEET, TUBE, ETC.

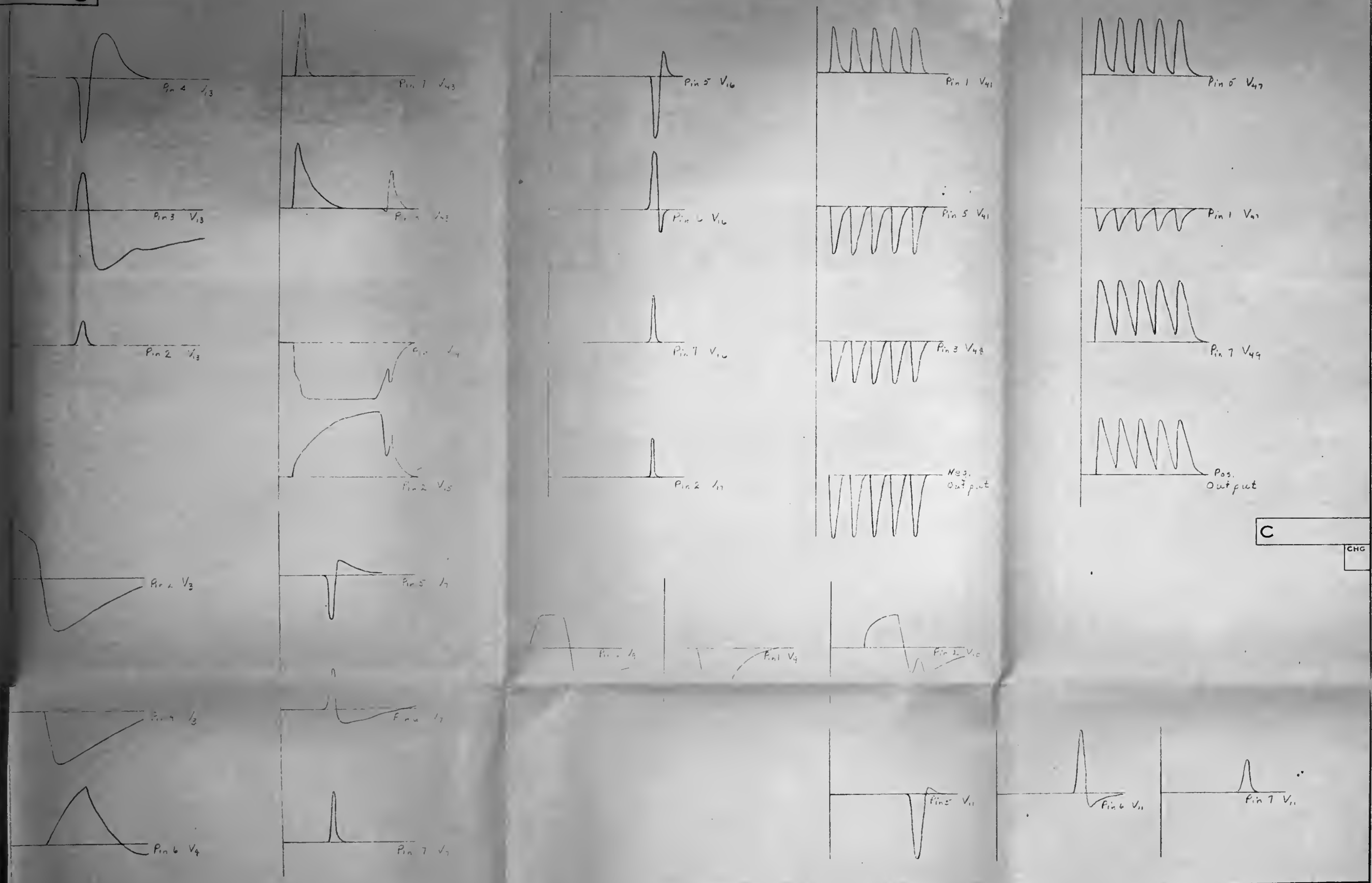
CHANGE:



Components shown are approximate in size. Exact locations not critical. Hole diameters as shown.

MAR 3 1952

REQ'D	DRAWING		ITEM	NAME	FIN.	ZONE	CIRCUIT SYMBOL
	USED ON	ASSY. DRWG.	QTY.	**MELPAR, INC. ELECTRONICS** ALEXANDRIA, VIRGINIA			
-1				Plan View of Pulse Modulator Showing Component Space Allocations			
				DRAWN BY	ENGINEER	MATERIAL	
				CHECKER	PROJ. ENGR.	FINISH	
B				APPROVED	SCALE 1:2	B	CHG.



These waveforms for[...] reference for a quick check. For detailed [...]forms showing amplitudes and time relationships, s[...] waveforms for individual channels included else[...] this report.

REQ'D	DRAWING	ITEM	NAME	FIN.	ZONE	CIRCUIT SYMBOL
1	PROJECT NO / NEXT ASSY	QTY.	**MELPAR, INC. ELECTRONICS** ALEXANDRIA, VIRGINIA			
			Modulator Waveforms.			

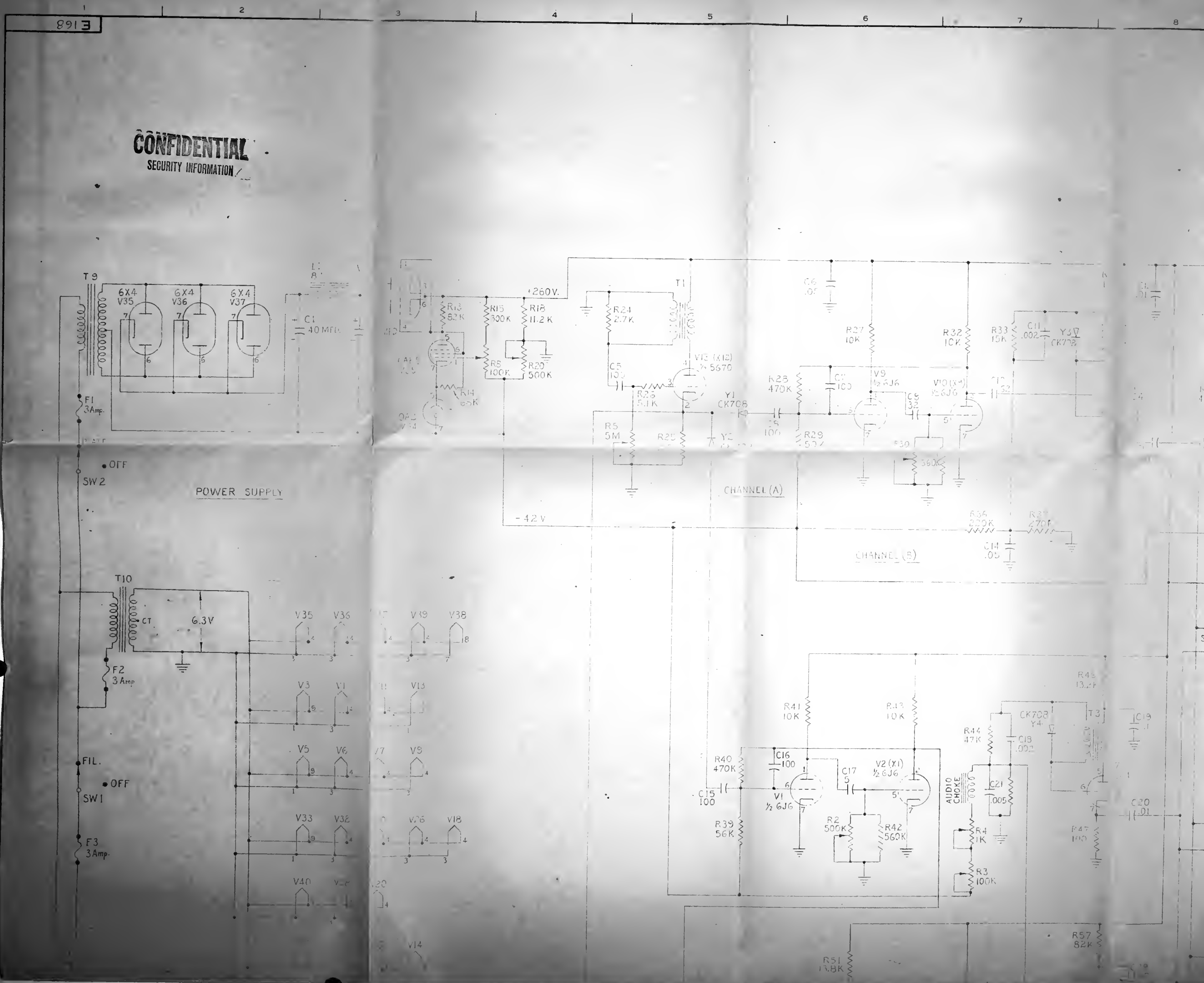
DRAWN BY	ENGINEER	MATERIAL
CHECKER	PROJ. ENGR.	FINISH
APPROVED	SCALE	C

DRAWING SIZE C — CHG.

ANGULAR ± DECIMALS ± FRACTIONS ± (UNLESS OTHERWISE SPECIFIED)
COMMERCIAL PUBLISHED TOLERANCES SHALL APPLY TO SIZES OF BAR, ROD, WIRE, SHEET, TUBE, ETC.

CHANGE

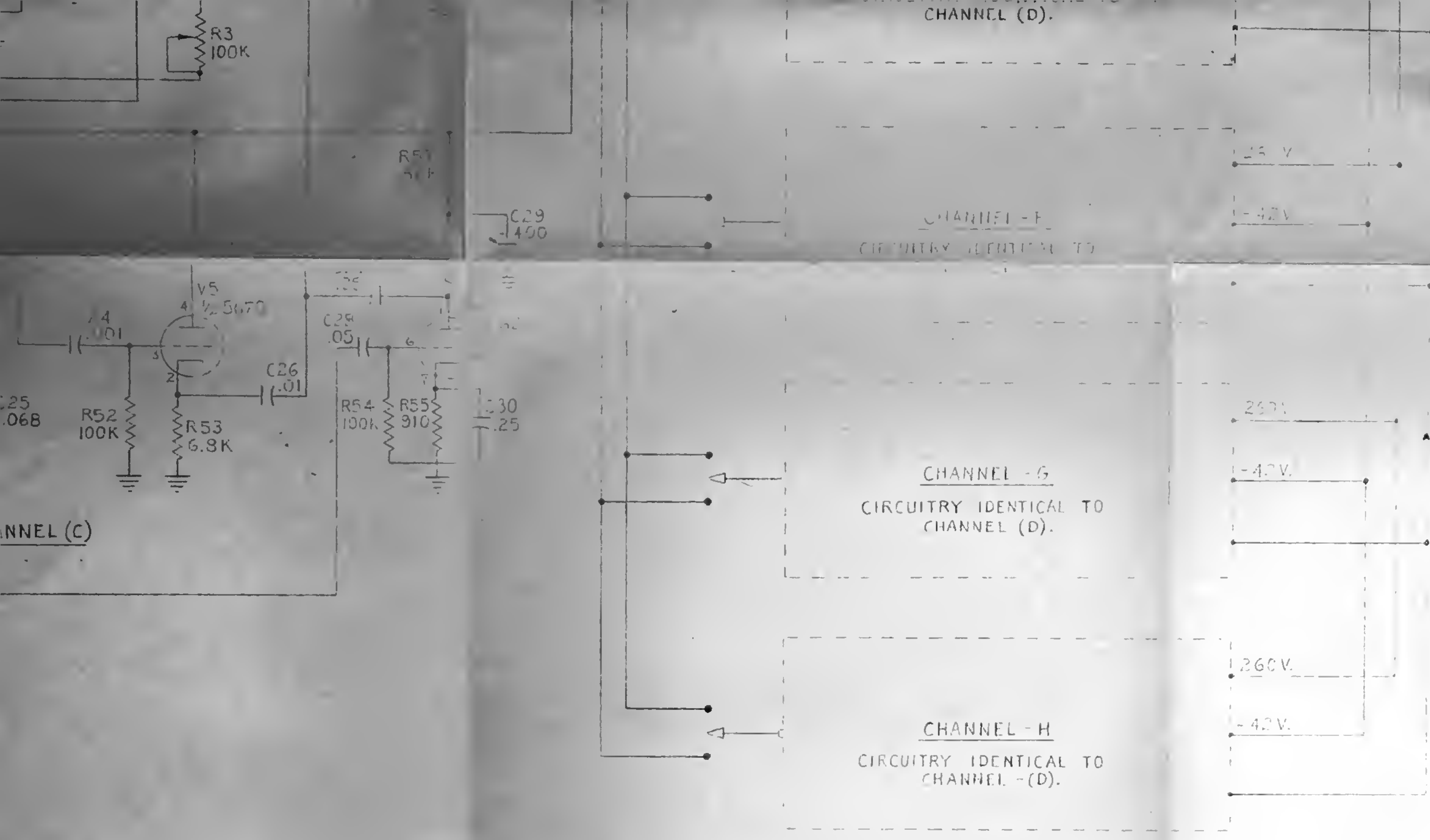
NO. 1020 CLEARPRINT TRACING PAPER COOPER TRENT WASH D C



E168
CONFIDENTIAL
SECURITY INFORMATION
POWER SUPPLY
CHANNEL (A)
CHANNEL (B)
T9
6X4 V35
6X4 V36
6X4 V37
C1 40 MFD
F1 3 Amp.
OFF
SW 2
T10
CT
6.3V
F2 3 Amp
FIL.
OFF
SW 1
F3 3 Amp.
+260V.
-42 V
R13 82K
R15 300K
R18 11.2 K
R8 100K
R20 500K
R14 65K
T1
R24 2.7K
C5 100
R26 5.1K
R5 5M
V12 (X12) ½ 5670
Y1 CK708
C6 .05
R27 10K
R28 470K
V9 ½ 6J6
R29
C8 33
V10 (X9) ½ 6J6
R30 560K
R32 10K
R33 15K
C11 .002
Y3 CK708
R36 220K
C14 .05
R41 10K
R43 10K
R40 470K
C16 100
C15 100
V1 ½ 6J6
C17 5
V2 (X1) ½ 6J6
R39 56K
R2 500K
R42 560K
R44 47K
CK708 Y4
C18 .002
T3
C19 .1
AUDIO CHOKE
C21 .005
R4 1K
R3 100K
C20 .01
R57 82K
R51 13.8K
V35
V36
V39
V38
V3
V1
V13
V5
V6
V9
V33
V32
V26
V18
V40
V14

CHANNEL (D)	CHANNEL (F)	[illegible]	CHANNEL (G)	CHANNEL (H)
V43	V44 (X-5)	[illegible]	V40	V40 (X-40)
V14	V18	[illegible]	V26	V30
V15 (X-14)	V19 (X-18)	[illegible]	V27 (X-26)	V31 (X-30)
V16	V20	[illegible]	V28	V32
V17	V21 (X-17)	[illegible]	V29 (X-25)	V33
R75	R89	[illegible]	R117	R131
R76	R90	[illegible]	R118	R132
R77	R91	[illegible]	R119	R133
R79	[illegible]	[illegible]	R120	[illegible]
[illegible]	[illegible]	[illegible]	R121	[illegible]

ANGULAR ±
DECIMALS ±
FRACTIONS ±
UNLESS OTHERWISE SPECIFIED
COMMERCIAL PUBLISHED TOLERANCES SHALL APPLY TO SIZES OF BAR, ROD, WIRE SHEET, TUBE, ETC.



V15 (X-14)	V19 (X-18)	[illegible] (X-22)	V27 (X-26)	V31 (X-30)
V16	V20	[illegible]	V28	V32
V17	V21 (X-1?)	[illegible]	V30 (X-25)	V33
R75	[illegible]	[illegible]	R117	R131
R74	[illegible]	[illegible]	R118	R132
R77	[illegible]	[illegible]	R119	R133
R78	[illegible]	[illegible]	R120	R134
R80	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	R91	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	R140
[illegible]	R99	[illegible]	[illegible]	R141
[illegible]	R100	[illegible]	[illegible]	R142
R87	R101	[illegible]	[illegible]	R143
R83	R102	[illegible]	R130	R144
R79	R93	[illegible]	R121	R135
C45	C53	[illegible]	C69	C77
C46	C54	[illegible]	C70	C78
C47	C55	[illegible]	C71	C79
C48	C56	[illegible]	[illegible]	C80
C49	C57	[illegible]	C73	C81
C50	C58	[illegible]	C74	C82
C51	C59	[illegible]	C75	C83
C52	C60	[illegible]	C76	C84
T4	T5	[illegible]	T7	T8
Y7	Y8	[illegible]	Y10	Y11
Y12	Y13	[illegible]	Y15	Y16
SW3	SW4	[illegible]	[illegible]	SW7

CROSS REFERENCE TABLE FOR [illegible] CHANNELS (D) THROUGH (H).

E168

CONFIDENTIAL
SECURITY INFORMATION

MAR 24 1952

ANGULAR ±
DECIMALS ±
FRACTIONS ±
UNLESS OTHERWISE SPECIFIED
COMMERCIAL PUBLISHED TOLERANCES SHALL APPLY TO SIZES OF BAR, ROD, WIRE SHEET, TUBE, ETC.

CHANGE

REQ'D	DRAWING	ITEM	NAME	FIN.	ZONE	CIRCUIT SYMBOL
1	153					

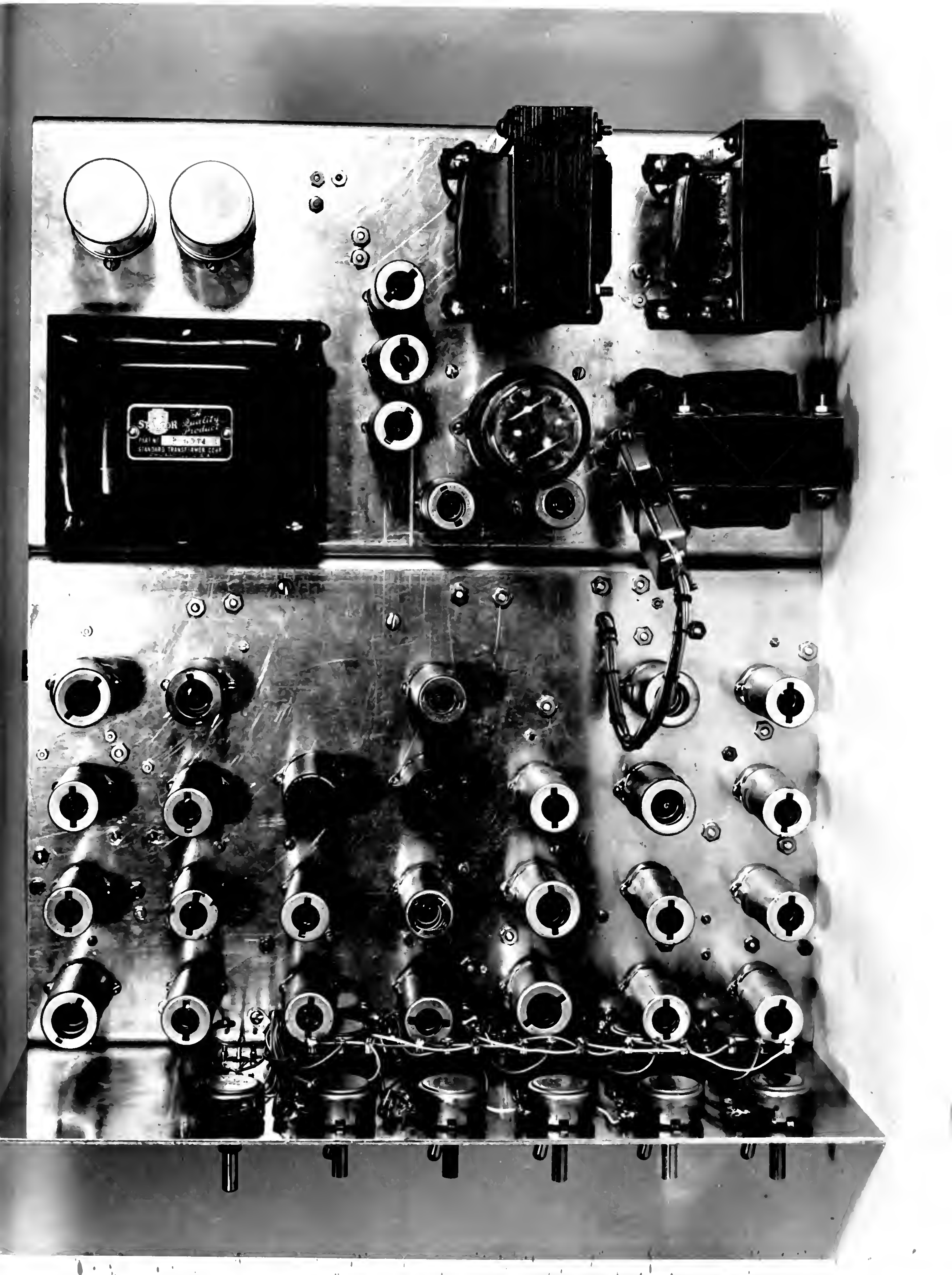
MELPAR, INC. ELECTRONICS
ALEXANDRIA, VIRGINIA

MODULATOR SCHEMATIC

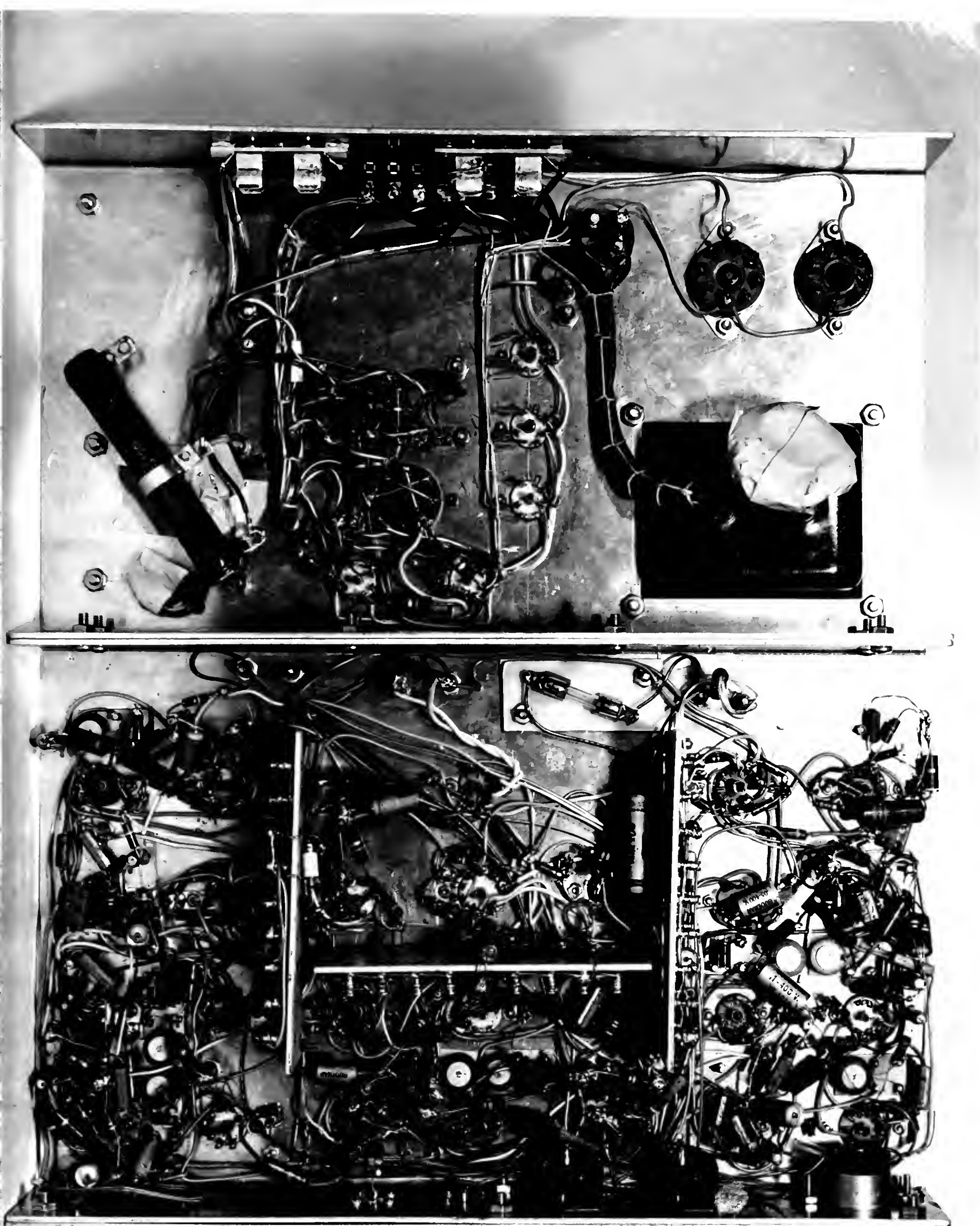
DRAWN BY	ENGINEER	MATERIAL
R.M. WALKER 3/20/52		
CHECKER	PROJ. ENGR.	FINISH
APPROVED	SCALE	E168

SIZE E

CHG.


A Quality Product
STANDARD TRANSFORMER CORP


Reg.
Fixed(B)
Wob.(C)
Coarse
Fine
Rep.(A)
Sync 'Out'
Fix —— Wob
Fix —— Wob
Fix —— Wob
Fix —— Wob
Fix —— Wob
Audio 'In'
Chan. D
Chan. E
Chan. F
Chan. G
Chan. H
Fil.
H.V.
Neg. Out
Pos. Out

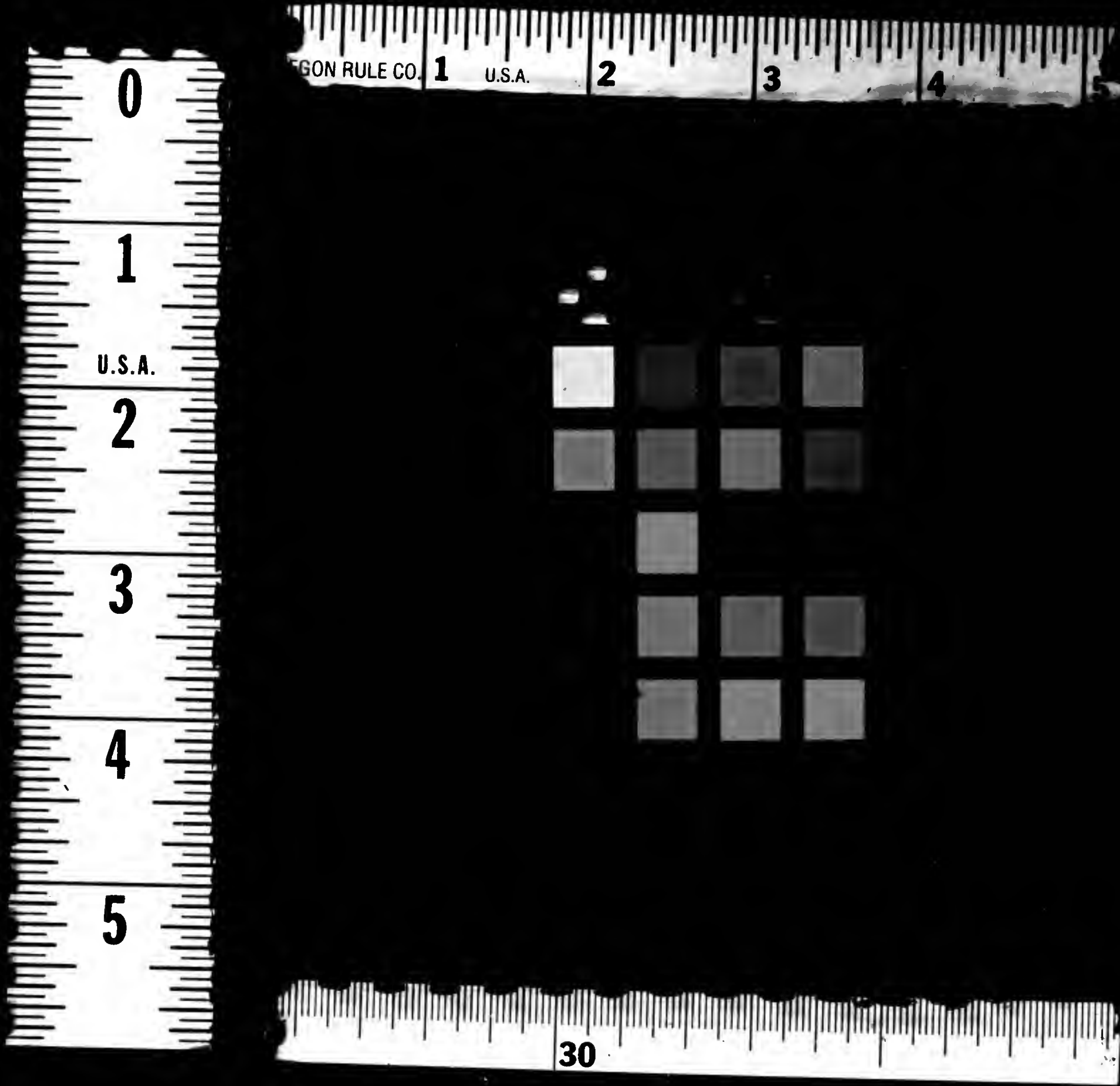


[illegible]

17 JUL 68

16547

R373 Rhinesmith 25028
A multiple micro-pulse generator.


GON RULE CO. 1 U.S.A. 2 3 4 5
0 1 U.S.A. 2 3 4 5
30